AD NUMBER
AD249786
LIMITATION CHANGES
TO: **Approved for public release; distribution is unlimited.**
FROM: **Distribution authorized to U.S. Gov't. agencies and their contractors; Administrative/Operational Use; OCT 1960. Other requests shall be referred to Wright Air Development Division, Wright-Patterson AFB, OH 45433.**
AUTHORITY
SEG ltr, 23 Jun 1967

WADD TECHNICAL REPORT 60-56
PART II

A COMPENDIUM OF THE PROPERTIES OF MATERIALS AT LOW TEMPERATURE (PHASE I)

PART II. PROPERTIES OF SOLIDS

Victor J. Johnson, General Editor

National Bureau of Standards
Cryogenic Engineering Laboratory

OCTOBER 196

WRIGHT AIR DEVELOPMENT DIVISION

WADD TECHNICAL REPORT 60-56
PART II

A COMPENDIUM OF THE PROPERTIES OF MATERIALS AT LOW TEMPERATURE (PHASE I)

PART I. PROPERTIES OF SOLIDS

Victor J. Johnson, General Editor

National Bureau of Standards
Cryogenic Engineering Laboratory

OCTOBER 1960

Materials Central
Contract No. AF 33(616)-58-4
Project No. 7360

WRIGHT AIR DEVELOPMENT DIVISION
AIR RESEARCH AND DEVELOPMENT COMMAND
UNITED STATES AIR FORCE
WRIGHT-PATTERSON AIR FORCE BASE, OHIO

2,500 – January 1961 – 16-706C

FOREWORD

This report was prepared by the National Bureau of Standards Cryogenic Engineering Laboratory under U. S. Air Force Contract No. 33(616)58-4. This contract was initiated under Project No. 8-(8-7360), "Thermophysical Properties of Cryogenic Materials", Task No. 73603. The work was administered under the direction of the Physics Laboratory, Directorate of Laboratories, Wright Air Development Division, with Mr. Paul W. Dimiduk acting as project engineer.

This report covers work conducted from January 1958 to March 1959.

The following members of the Cryogenic Engineering Laboratory Staff contributed to this phase of the compendium: D. B. Mann (task author for helium), Dr. F. E. E. Germann (task author for hydrogen), Dr. K. D. Timmerhaus* (task author for neon, nitrogen and carbon monoxide), John Macinko (task author for oxygen), D. A. Van Gundy, and W. J. Veigle (task authors for air), Dr. P. L. Barrick* (task author for argon), R. F. Robbins (task author for fluorine and methane), R. L. Powell (task author for thermal conductivity of solids), and Dr. R. J. Corruccini (task author for expansivity, specific heat and enthalpy of solids); R. B. Scott and E. H. Brown reviewed most of the data sheets, noted many inconsistencies and offered many suggestions for improving the validity and usefulness of the data; Dr. R. D. Goodwin planned the program for compiling the compendium and initiated work on it. (He also along with Dr. Corruccini, conferred with the sponsor (WADC) and Armour Research Foundation regarding the scope and arrangement of the compendium. The proposal and contract were evolved from this planning.) D. B. Chelton (literature searches for nitrogen and carbon monoxide); R. V. Smith** and R. B. Stewart*** (hydrogen literature searching); Dr. V. D. Arp and J. J. Gniewek compiled data on specific heat and enthalpy of solids; R. J. Rasmussen and B. D. Troyer, graduate students, assembled much of the data for typing and drafting of the data sheets; J. A. Brennan and J. R. Cahoon monitored completion of the data sheets and prepared check prints; W. W. Bulla and G. A. Reynolds drew most of the graphs; Genevieve Michela and Signe Hartley typed most of the data sheets; and D. E. Jordan assisted in final review and completion of the compendium. Many other staff members contributed to the compendium in numerous ways but it is difficult to name them all and identify their aid. The task was a huge one and all contributions were valuable.

Many others who were sent preliminary copies of this compilation contributed helpful suggestions and criticisms of the material which has materially improved the final presentation and its accuracy. The following is a partial list of such contribution: I. Simon and I. A. Black of A. D. Little Co., F. Din of British Oxygen Co., L. C. Matsch and staff of Linde Co., W. B. Mitchell of Convair Astronautics, T. I. Bell of British Royal Aircraft Establishment, Paul Hernandez of the University of California Radiation Laboratory, W. T. Ziegler of Georgia Institute of Technology, P. E. Liley of Purdue University, E. J. Dethke of National Cylinder Gas, W. E. Schaefer of Air Reduction Sales Co., and H. Ziebland of British Ministry of Aviation. Their help and the help of many others is gratefully acknowledged.

The efforts of Genevieve Michela in carefully supervising the many changes and corrections made throughout the compendium and preparing it for final publication are sincerely appreciated.

---

*Professor of Chemical Engineering, University of Colorado, employed part-time by the Cryogenic Engineering Laboratory.

**Assoc. Professor of Mechanical Engineering, Colorado State University, Fort Collins.

***Assoc. Professor of Mechanical Engineering, University of Colorado

ABSTRACT

This first phase of the Compendium covers ten properties of ten fluids (Part I), three properties of solids (Part II), and an extensive bibliography of references (Part III). Density, expansivity, thermal conductivity, specific heat and enthalpy, transition heats, phase equilibria, dielectric constants, adsorption, surface tension and viscosity for the solid, liquid and gas phases of helium, hydrogen, neon, nitrogen, oxygen, air, carbon monoxide, fluorine, argon and methane are given wherever adequate data could be collected. Thermal expansion, thermal conductivity and specific heat and enthalpy are given for a number of solids of interest in cryogenic engineering. Data sheets, primarily in graphic form, are presented from "best values" of data collected. The source of the material used, other references and tables of selected values with appropriate comments are furnished with each data sheet to document the data presented. Conversion tables and other helpful information are also included.

PUBLICATION REVIEW

This report has been reviewed and is approved.

FOR THE COMMANDER:

Jules I. Wittebort

JULES I. WITTEBORT
Chief, Thermophysics Branch
Physics Laboratory
Materials Central

TABLE OF CONTENTS*

---

* General Contents only; detailed contents given at the beginning of each chapter.

** Code designation sequence used in lieu of page numbers to permit internal expansion.

NOTE TO USER

This volume is intended basically as a loose-leaf report for continuous expansion and revision as new and revised data sheets are produced. It has been bound as an economical means of assembly and distribution. It is also punched for standard three hole binders that are available from many commercial sources. A simple method of removing the bound cover and loosening the sheets is to shear off approximately 1/16" of the bound edge in an ordinary printers shear.

Manuscript released for publication August 1960 as a WADD Technical Report.

INTRODUCTION

A. General Introduction to Phase I of the Compilation Program

In the past ten years there has been a greatly accelerated growth of interest and activity in cryogenic engineering. From a few industrial applications such as the liquefaction of oxygen and from laboratory scale research at low temperatures, the activity has spread to nuclear reactors, controlled thermonuclear reactions, high altitude flight, missiles and rockets, the use of cryogenic fuels and oxidants, nuclear powered rockets, and transportation of liquefied gases; to name a few areas of application in this ever widening field.

As a result of the increased cryogenic activity, and the rigorous technical demands that often occur in new applications, it soon became apparent that a great deal more information and data on the properties of materials at low temperatures is needed by design engineers and physicists than is now readily available to them. The Wright Air Development Division of the U. S. Air Force, which is conducting and sponsoring a large amount of engineering development involving cryogenics, arranged with the National Bureau of Standards to undertake a program of collecting and compiling data on the thermophysical properties of materials used in low temperature applications. The program was started early in 1958 by the Cryogenic Engineering Laboratory Staff and this compendium presents the first phase of the work.

The scope of this first phase includes as extensive a literature search as was deemed practical and the correlation and presentation of data on ten specified properties of ten of the most common cryogenic fluids. It also includes three of the more pertinent properties of a number of solids used at low temperatures. The specified temperature range of primary interest was from near absolute zero to 110°K. Where desirable and practicable, however, data are included for temperatures up to near room temperature (300°K). Upon the selection and presentation of the "best values" found in the literature graphical presentation of the data is also made where practicable. It was stipulated that the metric system of units be

used for the primary coordinates of graphs and that "English" or engineering units also be shown as alternate coordinates to aid design engineers not accustomed to metric units.

The plan adopted for organizing the compendium embodied two basic features. One was a "loose-leaf" design allowing more data to be added as it became available. The other concerned the numbering scheme for arranging the data sheets. Considering that there are a limited number of properties of materials and almost an unlimited number of materials that might eventually be of interest, the primary arrangement was made by properties and a secondary order established for materials. Each data sheet then is made complete and somewhat independent of any of the other data sheets. Each is assigned a code number by property and material classification and placed in the compendium in a corresponding order.

The data sheets are designed in such a manner as to serve both the design engineer who needs preselected values suitable for direct use and the researcher who is interested in the nature of the data and how it was derived. The "best values", or what are considered to be the most probable values, have been plotted as a full page graph whenever practicable with no encumbering deviations or alternate values. This is intended primarily for the design engineer. As complete a documentation as feasible is given to support each graph and to aid those interested or in need of a more thorough evaluation of the data. This includes the source of the data, other references of merit, brief comments concerning the data and a tabulation of values selected from the source. Occasionally, alternate values from other references are tabulated also for comparison purposes. In most cases the values are given just as they appeared in the source and accordingly the units are not necessarily the same as used on the graph. By doing this, possible conversion errors were eliminated and the full significance of the values retained.

This first phase of the program was divided into a number of tasks for assignment to qualified senior staff members. The task break-down for the fluids was by material and so there were ten such tasks. The breakdown for solids was made by property resulting in three additional tasks.

The person assigned a task is referred to as a "task author". It was the task author's responsibility to make as complete a literature search as practicable and record the scope of his search. He also selected "best values" from the references he found and made pertinent comments regarding the data. He then presented it to the "general editor" for preparation of the data sheets. Student aides from the University of Colorado (both graduates and undergraduates in engineering) were used extensively in preparing the detailed data sheets. They also assisted the senior staff members in identifying references in the literature search. The Cryogenic Data Center played an important role in actually obtaining documents for task authors. It also profited as a result of this assistance since the literature searches turned up nearly two thousand new references of interest in cryogenics.

Division of the work in the manner just described has both advantages and disadvantages over other arrangements. A major advantage is that use can be made of a great diversity of talent by seeking help from persons most familiar with the subject matter. On the other hand, these people are usually the ones that already have the greatest demands made on their time and so it is very difficult to achieve orderly progress of the work on a reasonable time schedule. A somewhat better arrangement from a scheduling standpoint might be to have about two experienced persons working full time instead of ten or more on a hit-and-miss basis. Two difficulties immediately become apparent. One is finding persons with broad enough experience to handle a wide cross section of subject matter as is represented in this work who would accept the tediousness of such a task for a year or more. The other is that no one or two persons can possess the general knowledge that is usually represented by a large number of persons each working in a somewhat specialized area. Present planning for the future phases of this work is to reach some kind of a compromise between the two plans, i.e. have at least one full time experienced person carrying the bulk of the search and correlation load but utilize numerous other staff members to review and criticize the data derived.

The next phase of the program (Phase II) is already well underway.

It covers the following additional properties for essentially the same materials as included in Phase I:

Compressibility Factor ($Z = PV/RT$)..............11.000*

Compressibility $\left[-\frac{1}{V}\left(\frac{dV}{dP}\right)_T\right]$ and

Compressibility Coefficient $\left[-\frac{P}{V}\left(\frac{dV}{dP}\right)_T\right]$......12.000

Thermal Conductivity Integrals $\left[\int_{T_0}^{T_1} \lambda\, dT\right]$.....13.000

Entropy (S)..................................14.000

Velocity of Sound............................15.000

Solubility (2 component mixtures of liquids and gases)...............................16.000

Electrical Resistivities.....................17.000

Ferromagnetic Properties.....................18.000

* This number represents the coding sequence.

It will be issued as a supplement to this first phase of the Compendium and will be arranged for uniform continuity. There also will, undoubtedly, be revisions and additions to the material issued here as inconsistencies and better data are discovered. Revised data sheets will be prepared and issued to supplant or supplement the current ones.

Comments on this compendium will be greatly appreciated. They should be sent to the Cryogenic Engineering Laboratory, attention of the general editor for the WADD Compendium. We would also appreciate being informed of any errors (typographical, or otherwise) that may be discovered and any new information that users may have that would enhance the value of this compilation.

B. Introduction to Part II

This Compendium is divided into three parts for convenience; Part I, Properties of Fluids; Part II, Properties of Solids: and Part III, Bibliography of References, Cross-Indexed.

The properties of solids included in this phase of the Compendium are: Thermal Expansion (2.000), Thermal Conductivity (3.000), and Specific Heat and Enthalpy (4.000). The solids covered are listed in the "Contents" for each property. (Code numbers for solids were grouped by classes as follows: .100 - Pure Metals; .200 - Non-Ferrous Alloys; .300 - Ferrous Alloys; .400 - Inorganic Compounds; and .500 - Organic Compounds.)

Data sheets are presented individually for each property and material combination that was found in the literature search. Property values for many materials of interest in the cryogenic engineering field and for certain temperature ranges are missing in the compilation. Such omission indicates that no information was found in the search and perhaps may be that no measurements have been made in those areas for those cases. Where information does exist but was not found in the search, it is planned that data sheets will be prepared as the information is received and added to this compilation. Likewise, where better information than now presented is developed or found, a revised data sheet will be prepared to replace the current one.

The graphical presentation of "best values" selected from data given in the literature is made on full-page graphs as far as practicable. Metric units are used for the primary coordinates, but "English" or engineering units are also given as alternate coordinates except in a few instances where the metric units are regularly used by engineers. (It might be noted that alternate use of calories and joules exists among some of the graphs. The joule is now the accepted metric unit of energy, but unfortunately some of the first graphs were prepared using calories and have not yet been redrawn.) Careful note should be made of the units used when picking values from a graph. Not only should the exact dimensions of the units be noted but also the magnitude of the unit. For instance, some units are given in watts, others in milliwatts or microwatts, etc. Also, occasionally there is

a note to "multiply by 10^{-3}" or "multiply value by 10^{-5}", etc. For all instances, this means to multiply the numerical value taken from the graph by the number given. It has no direct reference to the size of the unit. For example, a value of 317 may be read from a graph that has a note to "multiply by 10^{-4}". The actual value is .0317 of the units given. The curves on the graphs are often plotted for a limited temperature range because of the limitation of available data. It is dangerous to extrapolate such curves beyond the extent plotted because of transitions and other anomalies that frequently are present but not indicated.

Conversion tables of dimensional units pertinent to a particular property are given at the beginning of each property chapter. Other conversion tables of more general application have been included for users' convenience as appendixes.

C. Scope of Literature Searches

Specific literature searches were made by the task authors in an effort to survey as much of the published literature as possible on the thermo-physical properties of materials of interest in cryogenic engineering. The principal indexes and bibliography services used for searching out the desired literature were: Chemical Abstracts, Physics Abstracts, Engineering Index, Industrial Arts Index, ASME Seventy-Seven Year Index, Dissertation Abstracts, Bureau of Mines Bibliographies, and other published bibliographies. The usual procedure was to search the indexes of the various abstracts and note all items that might possibly pertain to the desired subject matter. A review of the actual abstracts of the referenced literature then indicated more conclusively whether the article was pertinent. Articles selected were then ordered from various library services and reviewed in full text. All articles that contained pertinent information were then listed in the applicable bibliography of references and considered in the selection of data. There is listed below the extent of the specific searches made for each task:

<u>Thermal Expansion of Solids</u>

a. Physical Abstracts 1898 thru 1957

b. A.S.M. Review of Metal Literature 1944 thru 1956

c. Metallurgical Abstracts 1931 thru 1956

d. Chemical Abstracts 1948 thru 1956

<u>Thermal Conductivity of Solids</u>

a. Chemical Abstracts: Volumes 1 thru 50 (1907 - 1956)

b. Physics Abstracts: 1900 thru 1956

c. Landolt-Bornstein Physikalisch-chemische Tabellen, Edited by W. A. Roth and K. Scheel (Julius Springer, Berlin) 5th ed., vol. 2, 1923; 5th ed., 1st supplement, vol. 1, 1927; 5th ed., 2nd supplement, vol. 2, 1931; 5th ed., 3rd supplement, vol. 3, 1936.

d. NBS Circular 556. <u>Thermal Conductivity of Metals and Alloys at Low Temperatures</u>; A Review of the Literature (1954)

<u>Specific Heat and Enthalpy of Solids</u>

a. Bureau of Mines Bulletin 477, 1950 covers inorganic substances up to 1948.

b. General Electric Company Research Laboratory Bulletin: <u>The Heat Capacities of the Elements Below Room Temperature</u> Compiled by C. A. Shiftman covers elements to 1952.

c. Physics Abstracts: 1948 thru 1957

d. Chemical Abstracts: 1948 thru 1956

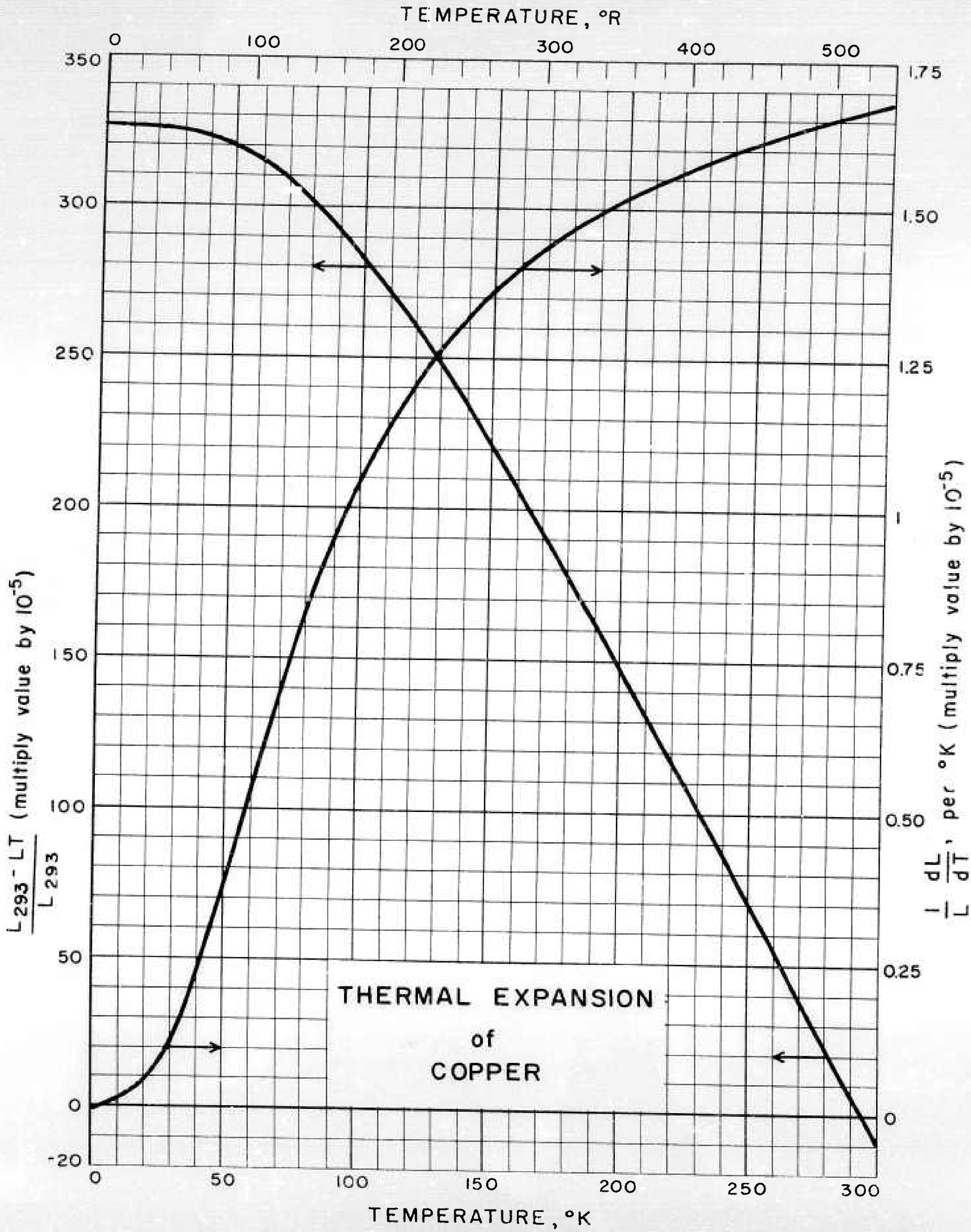
In addition to the specific searches listed above, a considerable number of references were found from listings on file in the Data Center that had been acquired somewhat at random. Also, inasmuch as most of the searches were for all properties of a particular material, many of the articles covered several materials. These additional references were added to the bibliographies of the other materials covered and were used by task authors in their evaluation and selection of data. A third additional source of references was from the documents themselves. Selected documents frequently listed references of a broader coverage than the material presented in it, and thus provided a more extensive range of properties. As a result, the actual scope of the literature searching was much greater than indicated by the specific searches as listed.

THERMAL EXPANSION of CRYOGENIC SOLIDS

CONTENTS

Author's Note

Values of thermal expansion are given in the form of (a) total fractional expansion, $\frac{L_{293} - L_T}{L_{293}}$; and (b) by coefficient of expansion $\frac{1}{L}\frac{dL}{dT}$, change per unit length per °K. For example the total fractional expansion (or contraction) for copper for a temperature change from 293.15°K (20°C) to 50°K is .00321 in./in., i.e., a bar will be .00321 inches shorter at 50°K per inch of length than it was at 293.15°K. However, the coefficient of expansion for copper at 50°K is .00038 in./in.-°K, i.e. it will expand (or contract).00038 inches per inch per °K temperature change from 50°K.


TEMPERATURE, °R
0
100
200
300
400
500
350
300
250
200
150
100
50
0
-20
1.75
1.50
1.25
1
0.75
0.50
0.25
0
$\frac{L_{293} - L_T}{L_{293}}$ (multiply value by 10^{-5})
$\frac{1}{L}\frac{dL}{dT}$, per °K (multiply value by 10^{-5})
THERMAL EXPANSION
of
COPPER
0
50
100
150
200
250
300
TEMPERATURE, °K

THERMAL EXPANSION OF COPPER

Source of Data:

Rubin, T., Altman, H. W. and Johnston, H. L., J. Am. Chem. Soc. 76, 5289-93 (1954)

Other References:

Simmons, R. O. and Balluffi, R. W., Phys. Rev. 108, 278-80 (1957)

Beenakker, J. J. M. and Swenson, C. A., Rev. Sci. Instr. 26, 1204 (1955)

Bijl, D. and Pullan H., Physica 21, 285 (1955)

Fraser, D. B. and Hollis-Hallet, A. C., Proc. 9th Intern. Congr. Refrig. 1, 1065 (1955)

Nix, F. C. and MacNair, D., Phys. Rev. 60, 597-605 (1941)

Aoyama, S. and Ito, T., Sci. Repts. Tohoku Univ. 27, 348-64 (1939)

Adenstedt, H., Ann. Physik 26, 69-96 (1936)

Simon, F. and Bergmann, R., Z. physik. Chem. 8, 255-80 (1930)

Krupkowski, A. and De Haas, W. J., Communs. Phys. Lab. Univ. Leiden 194b (1928)

Keesom, W. H., Van Agt, F. P. G. and Jansen, A. T. J., Proc. Acad. Sci. Amsterdam 29, 786-91 (1926)

Buffington, R. M. and Latimer, W. M., J. Am. Chem. Soc. 48, 2305-19 (1926)

Borelius, G. and Johansson, C. H., Ann. Physik 75, 23-36 (1924)

Lindemann, C. L., Phys. Z. 12, 1197-99 (1911)

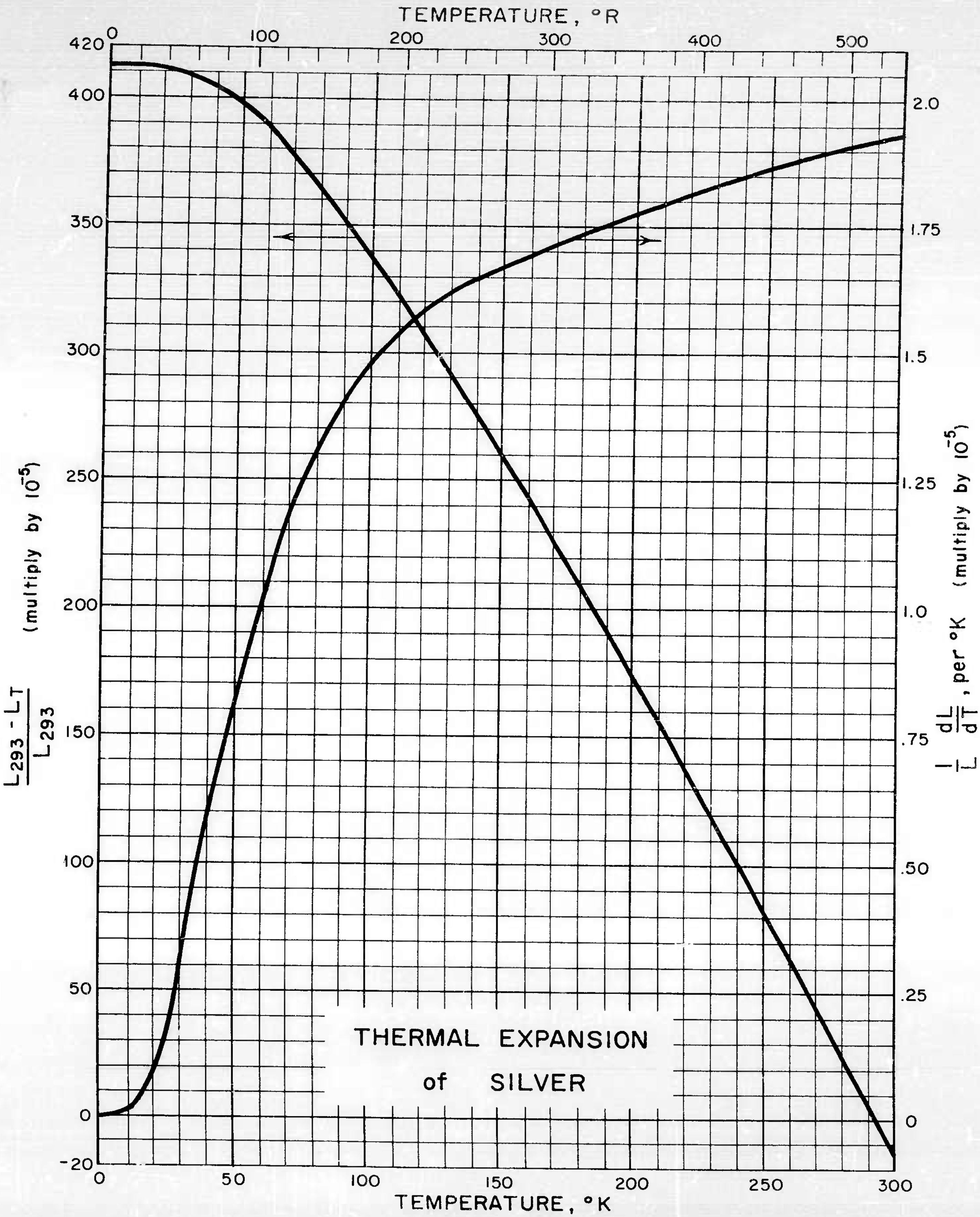
Henning, F., Ann. Physik (4) 22, 631-39 (1907)

Dorsey, H. G., Phys. Rev. 25, 88-102 (1907)

Table of Selected Values

Temp. °K	$\frac{L_{293} - L_T}{L_{293}}$	$\frac{1}{L}\frac{dL}{dT}$, per °K	Temp. °K	$\frac{L_{293} - L_T}{L_{293}}$	$\frac{1}{L}\frac{dL}{dT}$, per °K
0	326 x 10^{-5}	0	120	260 x 10^{-5}	1.20 x 10^{-5}
10	326 "	0.004 x 10^{-5}	140	235 "	1.32 "
20	326 "	.03 "	160	208 "	1.41 "
30	325 "	.10 "	180	179 "	1.47 "
40	324 "	.23 "	200	149 "	1.52 "
50	321 "	.38 "	220	118 "	1.56 "
60	316 "	.55 "	240	87 "	1.59 "
70	310 "	.70 "	260	55 "	1.62 "
80	302 "	.84 "	273.15	33 "	1.64 "
90	293 "	.95 "	280	22 "	1.65 "
100	283 "	1.05 "	293.15	0	1.67 "
			300	-11 "	1.68 "

JJG/JRC Issued: 12/1/59


TEMPERATURE, °R
0
100
200
300
400
500
420
400
350
300
250
200
150
100
50
0
-20
2.0
1.75
1.5
1.25
1.0
.75
.50
.25
0
$\frac{L_{293} - L_T}{L_{293}}$ (multiply by 10^{-5})
$\frac{1}{L}\frac{dL}{dT}$, per °K (multiply by 10^{-5})
THERMAL EXPANSION
of SILVER
0
50
100
150
200
250
300
TEMPERATURE, °K

THERMAL EXPANSION of SILVER

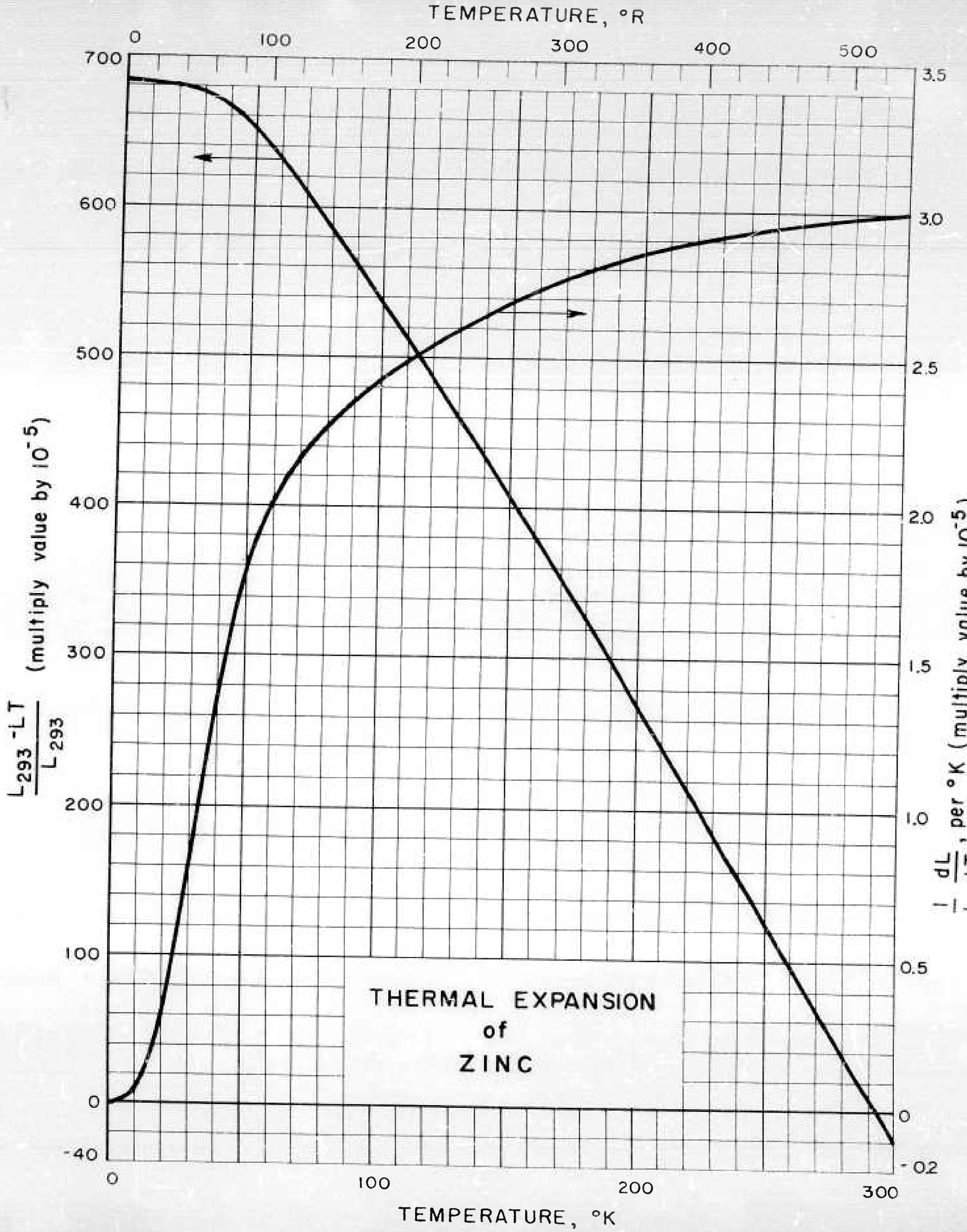
Sources of Data: Ebert 1928, Nix and MacNair 1942.

Other References: Ayres 1905, Buffington and Latimer 1926, Dorsey 1907, Henning 1907, Keesom and Jansen 1927, Lindemann 1911.

Table of Selected Values

Temp. °K	$\frac{L_{293} - L_T}{L_{293}}$	$\frac{1}{L}\frac{dL}{dT}$ per °K	Temp. °K	$\frac{L_{293} - L_T}{L_{293}}$	$\frac{1}{L}\frac{dL}{dT}$ per °K
0	413 x 10^{-5}	0	120	308 x 10^{-5}	1.59 x 10^{-5}
10	413 "	0.01 x 10^{-5}	140	276 "	1.65 "
20	412 "	.1 "	160	242 "	1.69 "
30	410 "	.3 "	180	208 "	1.73 "
40	405 "	.6 "	200	173 "	1.77 "
50	398 "	.8 "	220	137 "	1.81 "
60	389 "	1.0 "	240	100 "	1.85 "
70	378 "	1.2 "	260	63 "	1.88 "
80	366 "	1.3 "	273	38 "	1.90 "
90	353 "	1.36 "	280	25 "	1.90 "
100	339 "	1.46 "	293	0 "	1.91 "
			300	-13 "	1.91 "

RJC Issued: 6/11/59


TEMPERATURE, °R
0
100
200
300
400
500
700
600
500
400
300
200
100
0
-40
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0
-0.2
$\frac{L_{293} - L_T}{L_{293}}$ (multiply value by 10^{-5})
$\frac{1}{L}\frac{dL}{dT}$, per °K (multiply value by 10^{-5})
THERMAL EXPANSION
of
ZINC
0
100
200
300
TEMPERATURE, °K

THERMAL EXPANSION of ZINC

Source of Data:

Grüneisen, E. and Goens, E., Z. Physik. 29, 141 (1924)

Other References:

Dorsey, H. G., Phys. Rev. 27, 1 (1908)

Grüneisen, E., Ann. Physik. 33, 33 (1910)

Head, E. L. and Laquer, H. L., AECD-3706 (1952)

Lindemann, C. L., Physik. Z. 12, 1197-9 (1911)

McLennan, J. C. and Monkman, R. J., Trans. Roy. Soc. Can. III 23, 255-67 (1929)

Comments:

The data on zinc are discordant. The differences found among polycrystalline samples (Dorsey, Grüneisen, Head and Laquer, Lindemann) are attributable to the high degree of anisotropy of the zinc crystal which is shown by the data of Grüneisen and Goens in Table I. Evidently, appreciable preferred orientation is present in most polycrystalline zinc.

Table II has been derived from Table I and gives the average linear expansion. This is presumed to be representative of polycrystalline zinc that is without preferred orientation of crystallites. The expansion coefficients of Dorsey and of Head and Laquer are up to 20 per cent lower than those of Table II while those of Grüneisen and of Lindemann are less than one third as great. The expansions of various samples of polycrystalline zinc could conceivably cover a wide range of values between the limits set by the data of Table I.

Table I

Expansion Coefficients of Single Crystal Zinc
Parallel and Perpendicular to the Hexagonal Axis

T_2 °K	T_1 °K	$\frac{1}{L_{293}} \times \frac{L_2 - L_1}{T_2 - T_1}$ $\parallel$	$\frac{1}{L_{293}} \times \frac{L_2 - L_1}{T_2 - T_1}$ $\perp$
293	253	6.43×10^{-5}	1.25×10^{-5}
253	213	6.51 "	1.13 "
213	173	6.54 "	1.01 "
173	133	6.56 "	.83 "
133	93	6.44 "	+ .50 "
86	20	5.25 "	- .21 "

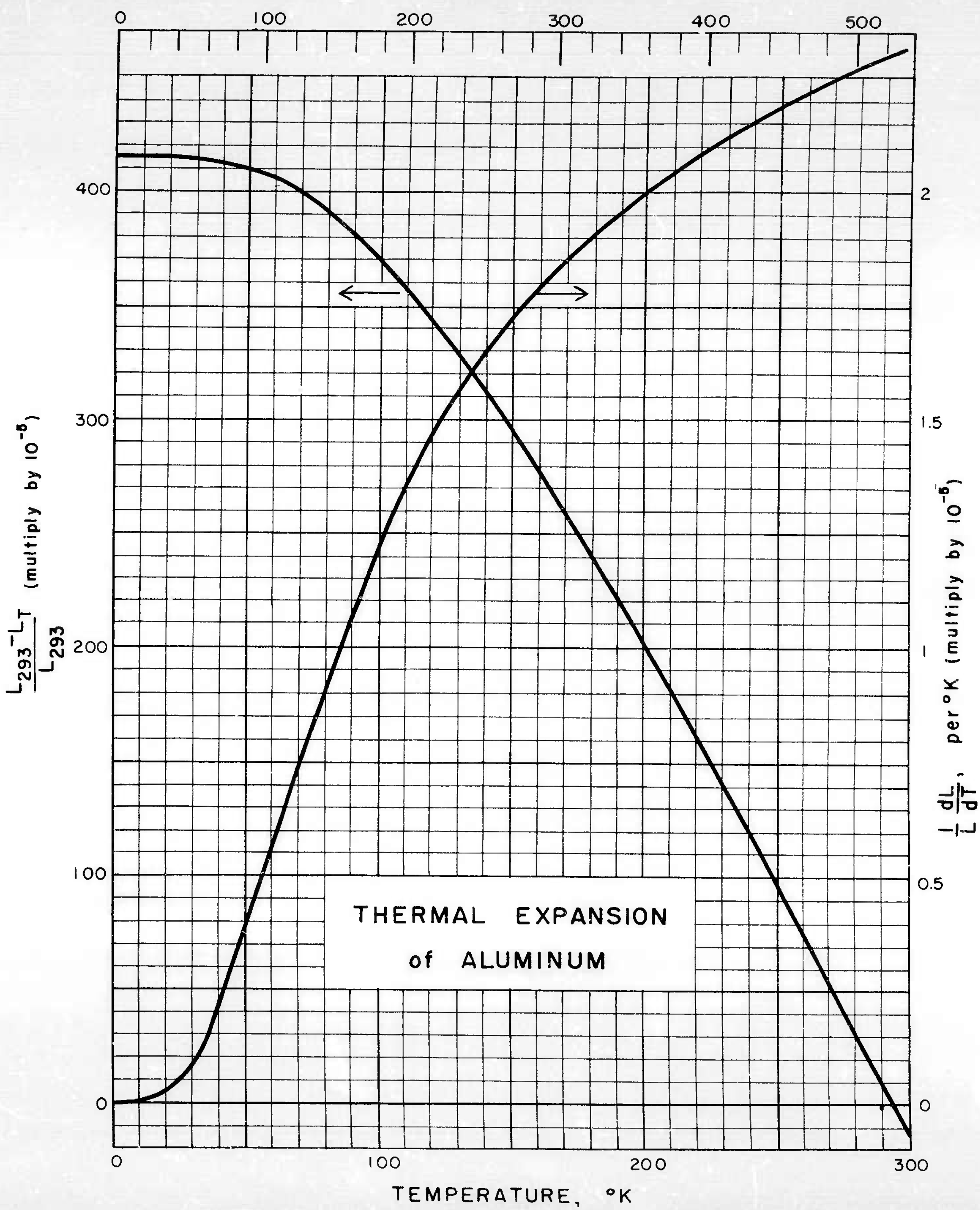
THERMAL EXPANSION of ZINC (Cont.)

Table II

AVERAGE EXPANSION of ZINC*

Temp. °K	$\frac{L_{293} - L_T}{L_{293}}$	$\frac{1}{L}\frac{dL}{dT}$, per °K	Temp. °K	$\frac{L_{293} - L_T}{L_{293}}$	$\frac{1}{L}\frac{dL}{dT}$, per °K
0	683×10^{-5}	0	120	492×10^{-5}	2.53×10^{-5}
10	683 "	$.03 \times 10^{-5}$	140	440 "	2.63 "
20	682 "	.3 "	160	386 "	2.73 "
30	677 "	.8 "	180	331 "	2.81 "
40	667 "	1.3 "	200	274 "	2.87 "
50	652 "	1.7 "	220	216 "	2.91 "
60	633 "	2.1 "	240	157 "	2.94 "
70	611 "	2.2 "	260	98 "	2.96 "
80	588 "	2.3 "	273	60 "	2.97 "
90	565 "	2.36 "	280	39 "	2.98 "
100	541 "	2.42 "	293	0	2.99 "
			300	-21 "	3.00 "

* Calculated on the basis: $\left(\frac{1}{L} \times \frac{dL}{dT}\right)_{av} = \left(\frac{1}{3L} \times \frac{dL}{dT}\right)_{\parallel} + \left(\frac{2}{3L} \times \frac{dL}{dT}\right)_{\perp}$


TEMPERATURE, °R
0
100
200
300
400
500
400
300
200
100
0
$\frac{L_{293}-L_T}{L_{293}}$ (multiply by 10^{-5})
2
1.5
1
0.5
0
$\frac{1}{L}\frac{dL}{dT}$, per °K (multiply by 10^{-5})
THERMAL EXPANSION
of ALUMINUM
0
100
200
300
TEMPERATURE, °K

THERMAL EXPANSION of ALUMINUM

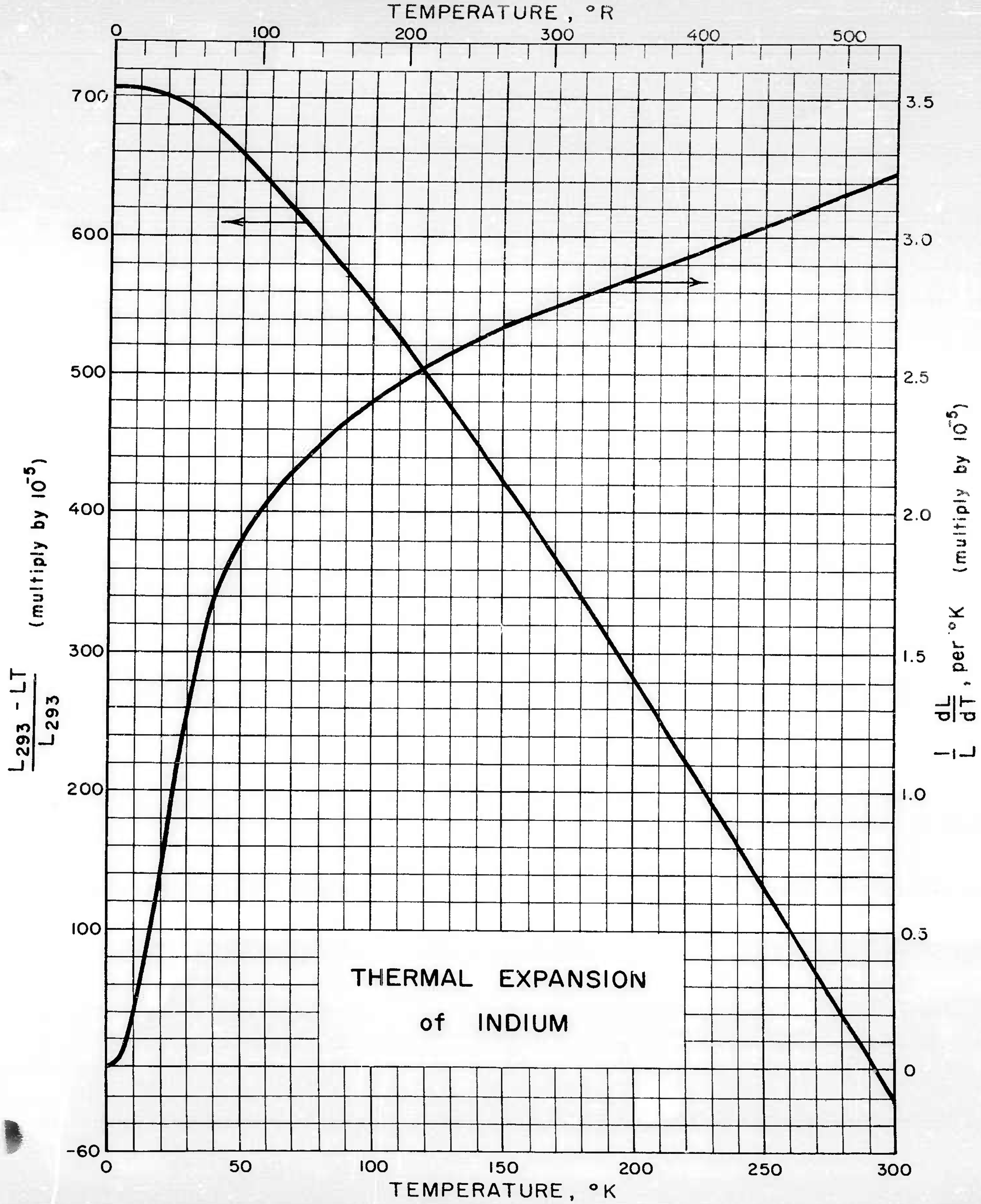
Source of Data: Altman, Rubin and Johnston 1954.

Other References: Ayres 1905, Bijl and Pullan 1955, Buffington and Latimer 1926, Ebert 1928, Gibbons 1958, Henning 1907, Hume-Rothery and Strawbridge 1947, Lindemann 1911, Nix and MacNair 1941.

Table of Selected Values

Temp. °K	$\frac{L_{293} - L_T}{L_{293}}$	$\frac{1}{L}\frac{dL}{dT}$ per °K	Temp. °K	$\frac{L_{293} - L_T}{L_{293}}$	$\frac{1}{L}\frac{dL}{dT}$ per °K
0	415×10^{-5}	0	120	343×10^{-5}	1.46×10^{-5}
10	415 "	0.005×10^{-5}	140	312 "	1.65 "
20	415 "	.02 "	160	277 "	1.79 "
30	414 "	.09 "	180	240 "	1.90 "
40	413 "	.22 "	200	201 "	2.00 "
50	410 "	.38 "	220	160 "	2.08 "
60	405 "	.55 "	240	118 "	2.15 "
70	399 "	.74 "	260	75 "	2.21 "
80	391 "	.91 "	273	45 "	2.25 "
90	381 "	1.07 "	280	30 "	2.27 "
100	370 "	1.22 "	293	0 "	2.30 "
			300	-16 "	2.32 "

RJC Issued: 6/15/59


TEMPERATURE, °R
0
100
200
300
400
500
700
600
500
400
300
200
100
-60
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0
$\frac{L_{293} - L_T}{L_{293}}$ (multiply by 10^{-5})
$\frac{1}{L}\frac{dL}{dT}$, per °K (multiply by 10^{-5})
THERMAL EXPANSION
of INDIUM
0
50
100
150
200
250
300
TEMPERATURE, °K

THERMAL EXPANSION of INDIUM

Source of Data: Swenson 1955

Other References: Hidnert and Blair 1943

Discussion: In the two investigations above, the experimental methods and sample purities were very similar. Yet the two points by Hidnert and Blair, $(L_{273} - L_{195}) / L_{273}$ and $(L_{273} - L_{83}) / L_{273}$, are respectively 7% and 4% less than Swenson's corresponding points. Swenson's data have been adopted solely because they include more points over a wider temperature range.

Table of Selected Values

Temp. °K	$\frac{L_{293} - L_T}{L_{293}}$	$\frac{1}{L}\frac{dL}{dT}$ per °K	Temp. °K	$\frac{L_{293} - L_T}{L_{293}}$	$\frac{1}{L}\frac{dL}{dT}$ per °K
0	706×10^{-5}	0.	120	500×10^{-5}	2.52×10^{-5}
10	706 "	0.2×10^{-5}	140	448 "	2.63 "
20	701 "	0.7 "	160	394 "	2.72 "
30	691 "	1.3 "	180	339 "	2.79 "
40	676 "	1.7 "	200	282 "	2.86 "
50	658 "	1.91 "	220	224 "	2.93 "
60	638 "	2.04 "	240	165 "	3.01 "
70	617 "	2.15 "	260	104 "	3.08 "
80	595 "	2.24 "	273	63 "	3.13 "
90	572 "	2.32 "	280	42 "	3.15 "
100	549 "	2.39 "	293	0 "	3.20 "
			300	-22	3.22 "

RJC Issued: 6/15/59

THERMAL EXPANSION of CARBON (GRAPHITE)

Sources of Data:

Baskin, Y. and Meyer, L., Phys. Rev. 100, 544 (1955)

Cohen, E. and Olie, J., Z. physik Chem. 71, 385-400 (1910)

Dewar, J., Proc. Roy. Soc. (London) 70, 237-46 (1902)

Erfling, H. D., Ann. Physik 34, 136-60 (1939)

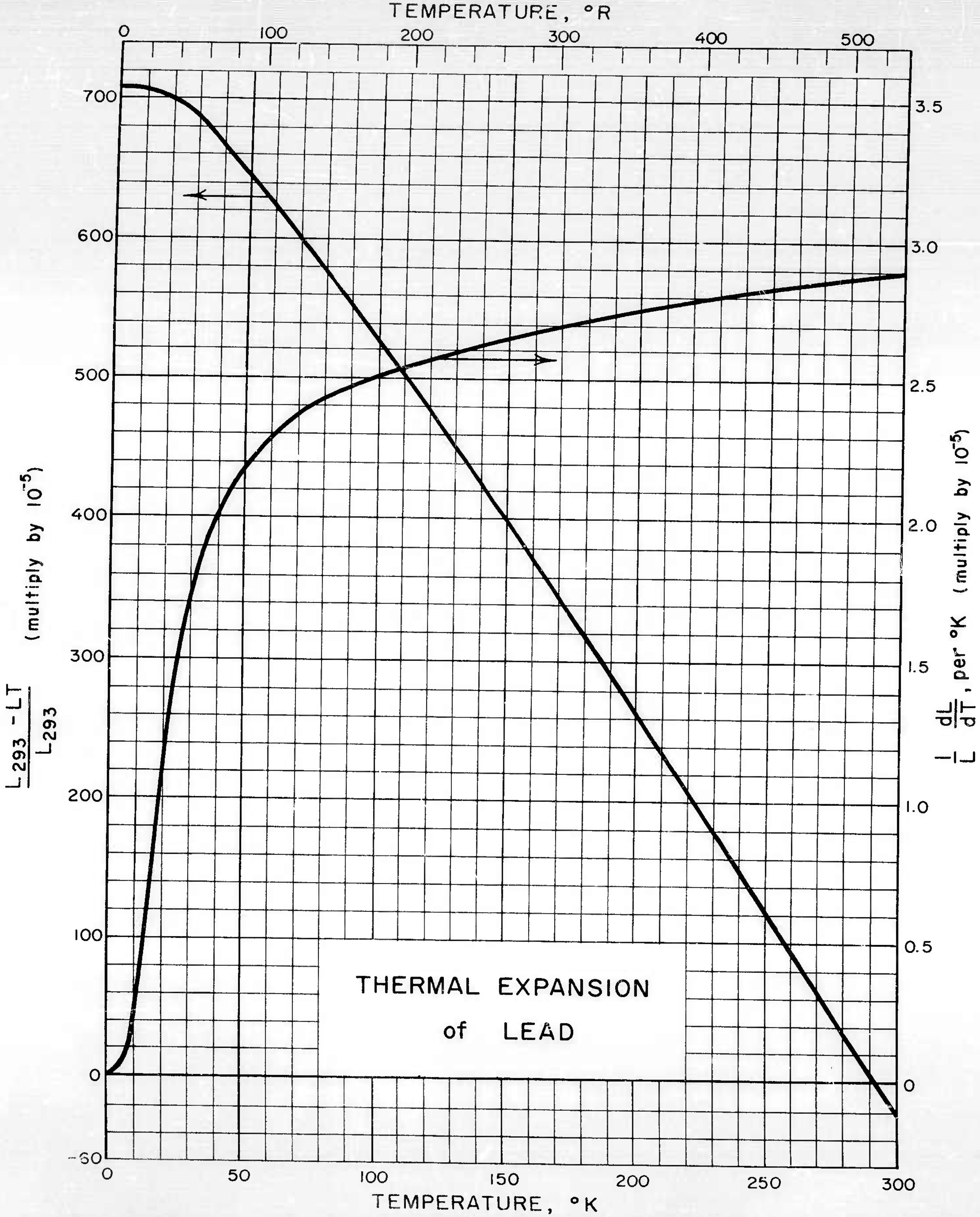
Walker, P. L., McKinstry, H. A. and Wright, C. C., Ind. Eng. Chem. 45, 1711 (1953)

Comments:

The macroscopic thermal expansion of polycrystalline graphite has not been measured at low temperatures. Baskin and Meyer by x-ray methods obtained 28×10^{-6} for $\bar{\alpha}_c$, the mean expansion coefficient from 78° to 297°K in the c-direction (normal to the laminae) for polycrystalline artificial graphite. This result agrees closely with Walker et al who obtained the constant value 29×10^{-6} from high temperatures down to 77°K. Baskin and Meyer found the corresponding coefficient for the a-direction, $\bar{\alpha}_a$ (parallel to the laminae) to be zero within experimental error, as was $\bar{\alpha}_c$ in the interval, 4° to 78°K. With a single crystal the values $\bar{\alpha}_c = (22 \pm 1) \times 10^{-6}$ in the range 78° to 297°K, and $\bar{\alpha}_c = (7 \pm 3) \times 10^{-6}$ in the range 4.2° to 78°K, were obtained. Erfling determined precise values of α_a for a natural graphite ranging from 6.6×10^{-6} at room temperature to 2.3×10^{-6} at about 90°K. Cohen and Olie obtained a mean volume expansion coefficient for a natural graphite over the interval 110° to 295°K which when divided by 3 gives an average linear expansion coefficient of 6×10^{-6}. Dewar similarly obtained 24×10^{-6} in the interval 85° to 290°K.

From these discordant results we can estimate that a polycrystalline artificial graphite will probably have a mean α between room temperature and liquid air temperatures within a factor of two of the value 10×10^{-6} per °K. However much lower values for room temperature can be found in the literature

RJC Issued: 12/1/59


TEMPERATURE, °R
0
100
200
300
400
500
700
600
500
400
300
200
100
0
-60
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0
$\frac{L_{293} - L_T}{L_{293}}$ (multiply by 10^{-5})
$\frac{1}{L}\frac{dL}{dT}$, per °K (multiply by 10^{-5})
THERMAL EXPANSION
of LEAD
0
50
100
150
200
250
300
TEMPERATURE, °K

THERMAL EXPANSION of LEAD

Sources of Data: Dheer and Surange 1958, Ebert 1928, Nix and MacNair 1942, Olsen and Rohrer 1957.

Other References: Dorsey 1908, Gruneisen 1910, Head and Laquer 1952, Lindemann 1911, McLennan, Allen and Wilhelm 1931.

Discussion: Superconducting lead has a slightly greater volume and a slightly smaller expansion coefficient than normal lead according to data by Olsen and Rohrer covering the region from 1° to the transition temperature, 7.2°K. For example, the difference in expansion coefficients at 5°K is about 10%.

Table of Selected Values

Temp. °K	$\frac{L_{293} - L_T}{L_{293}}$	$\frac{1}{L}\frac{dL}{dT}$ per °K	Temp. °K	$\frac{L_{293} - L_T}{L_{293}}$	$\frac{1}{L}\frac{dl}{dT}$ per °K
0	708×10^{-5}	0	120	477×10^{-5}	2.56×10^{-5}
5	708 "	0.03×10^{-5}	140	425 "	2.63 "
10	707 "	0.32 "	160	372 "	2.68 "
20	700 "	1.1 "	180	318 "	2.72 "
30	686 "	1.7 "	200	263 "	2.75 "
40	667 "	2.0 "	220	208 "	2.78 "
50	646 "	2.2 "	240	152 "	2.82 "
60	624 "	2.3 "	260	96 "	2.85 "
70	601 "	2.4 "	273	58 "	2.88 "
80	577 "	2.4 "	280	38 "	2.89 "
90	552 "	2.5 "	293	0	2.9 "
100	528 "	2.5 "	300	-20	2.9 "

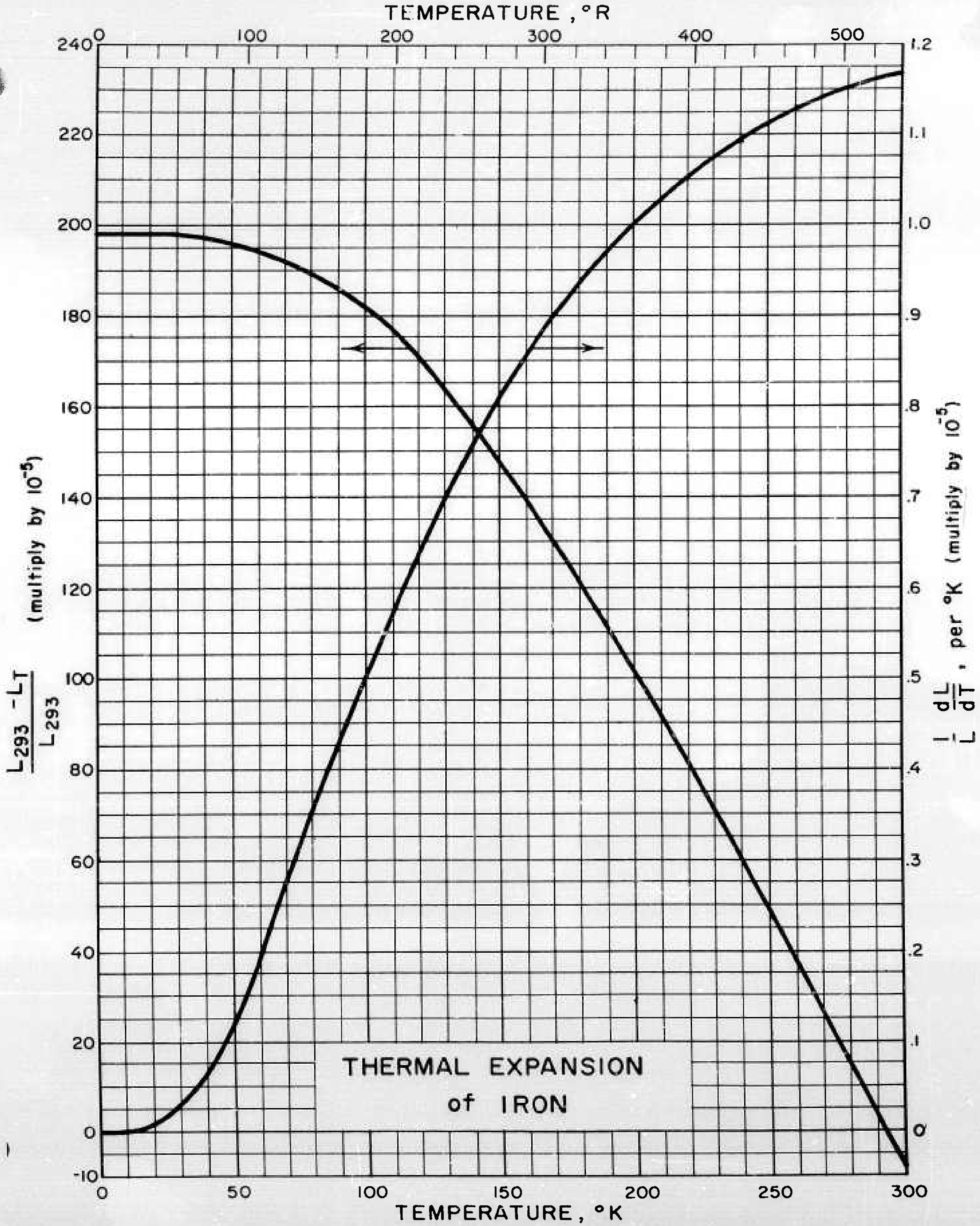
THERMAL EXPANSION of TIN (GRAY)

References: Thewlis and Davey 1954

Discussion: Gray tin is a brittle form with diamond-type lattice that is stable below 18°C. The ordinary ductile variety of tin (white tin) if pure may transform to gray tin at low ambient temperatures but is stabilized by the presence of impurities.

Data: The data cover the range -130 to +20°C and are represented by a constant expansion coefficient,

$$\frac{1}{L}\frac{dL}{dT} = 0.47 \times 10^{-5} \text{ per °C.}$$


TEMPERATURE, °R
0
100
200
300
400
500
240
220
200
180
160
140
120
100
80
60
40
20
0
-10
1.2
1.1
1.0
.9
.8
.7
.6
.5
.4
.3
.2
.1
0
$\frac{L_{293} - L_T}{L_{293}}$ (multiply by 10^{-5})
$\frac{1}{L}\frac{dL}{dT}$, per °K (multiply by 10^{-5})
THERMAL EXPANSION
of IRON
0
50
100
150
200
250
300
TEMPERATURE, °K

THERMAL EXPANSION of IRON

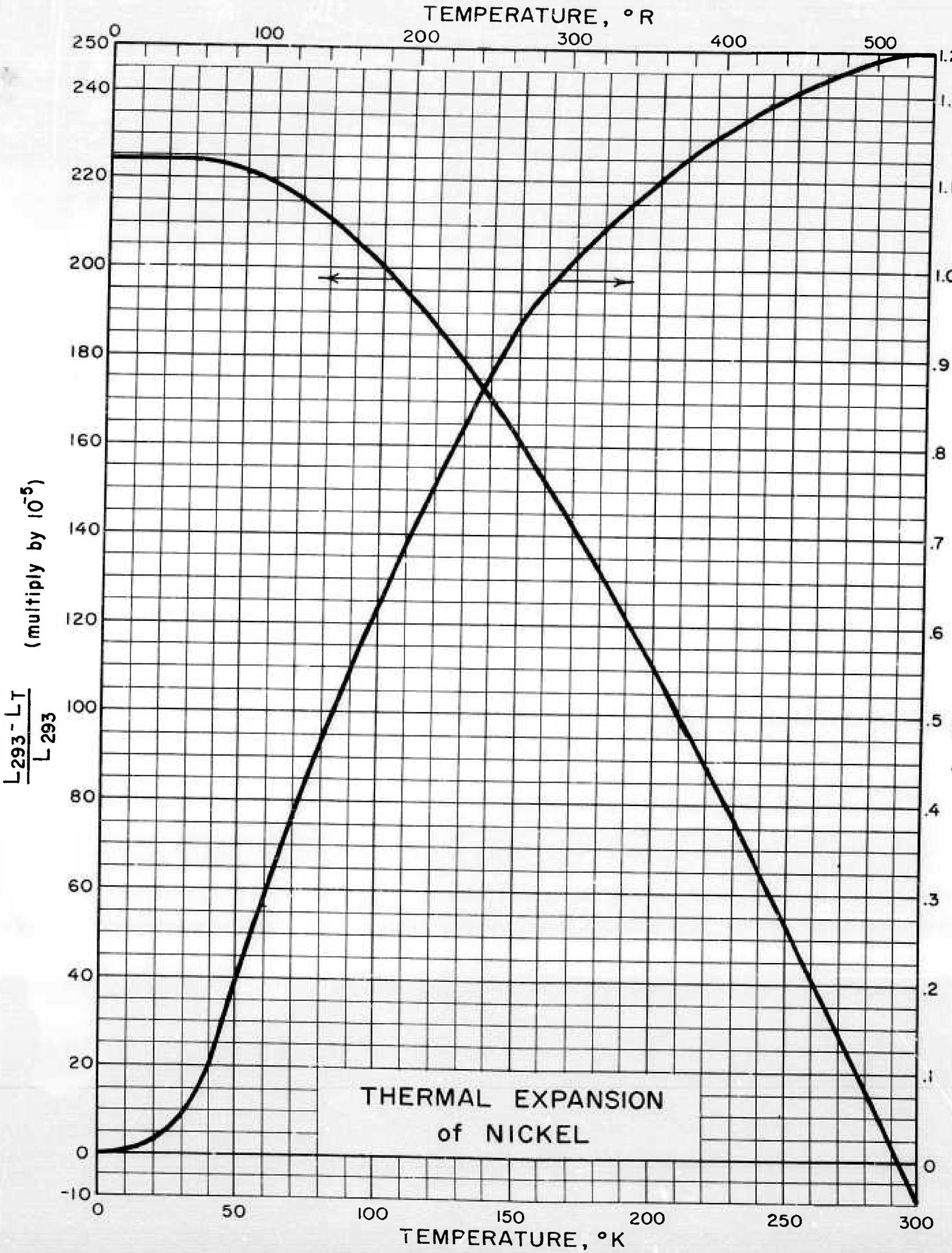
Sources of Data: Ebert 1928, Nix and MacNair 1941

Other References: Adenstedt 1936, Dorsey 1907, Simon and Bergmann 1930.

Table of Selected Values

Temp. °K	$\frac{L_{293} - L_T}{L_{293}}$	$\frac{1}{L}\frac{dL}{dT}$ per °K	Temp. °K	$\frac{L_{293} - L_T}{L_{293}}$	$\frac{1}{L}\frac{dL}{dT}$ per °K
0	198 x 10^{-5}	0	140	156 x 10^{-5}	0.76 x 10^{-5}
20	198 "	0.01 x 10^{-5}	160	140 "	0.86 "
30	198 "	.03 "	180	122 "	0.94 "
40	197 "	.07 "	200	102 "	1.00 "
50	196 "	.13 "	220	82 "	1.05 "
60	195 "	.20 "	240	60 "	1.09 "
70	192 "	.28 "	260	38 "	1.13 "
80	189 "	.35 "	273	23 "	1.14 "
90	185 "	.42 "	280	15 "	1.15 "
100	181 "	.49 "	293	0 "	1.16 "
120	170 "	.63 "	300	-8 "	1.17 "

RJC Issued: 6/5/59


TEMPERATURE, °R
0
100
200
300
400
500
250
240
220
200
180
160
140
120
100
80
60
40
20
0
-10
1.25
1.2
1.1
1.0
.9
.8
.7
.6
.5
.4
.3
.2
.1
0
$\frac{L_{293} - L_T}{L_{293}}$ (multiply by 10^{-5})
$\frac{1}{L}\frac{dL}{dT}$, per °K (multiply by 10^{-5})
THERMAL EXPANSION
of NICKEL
0
50
100
150
200
250
300
TEMPERATURE, °K

THERMAL EXPANSION of NICKEL

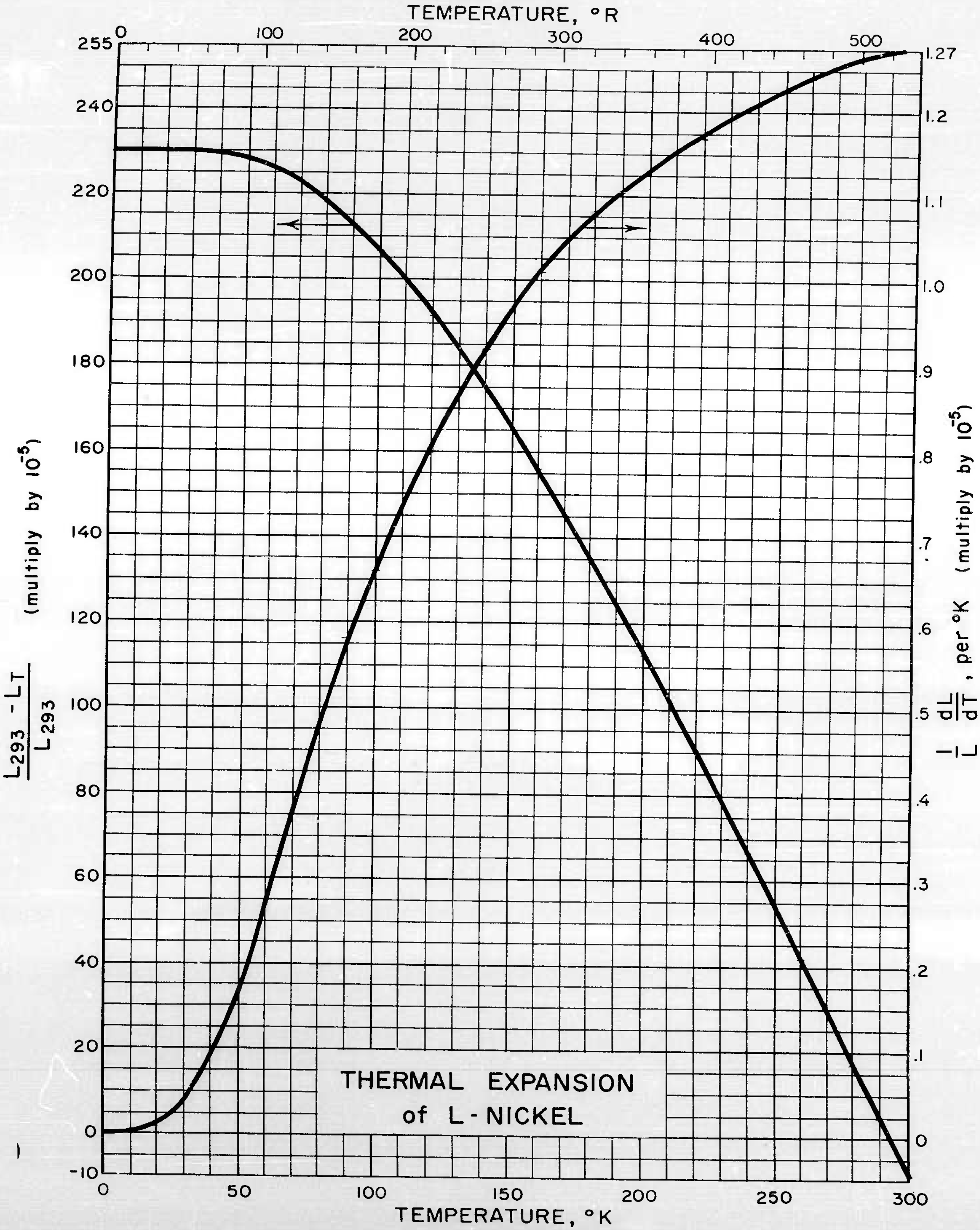
Sources of Data: Krupkowski and DeHaas 1928, Nix and MacNair 1941.

Other References: Adenstedt 1936, Altman, Rubin and Johnston 1954, Aoyama and Ito 1939, Disch 1921, Henning 1907, Simon and Bergmann 1930.

Table of Selected Values

Temp. °K	$\frac{L_{293} - L_T}{L_{293}}$	$\frac{1}{L}\frac{dL}{dT}$ per °K	Temp. °K	$\frac{L_{293} - L_T}{L_{293}}$	$\frac{1}{L}\frac{dL}{dT}$ per °K
0	224×10^{-5}	0.	140	171×10^{-5}	0.88×10^{-5}
20	224 "	0.02×10^{-5}	160	152 "	0.98 "
30	224 "	.05 "	180	132 "	1.05 "
40	223 "	.10 "	200	111 "	1.10 "
50	221 "	.19 "	220	88 "	1.15 "
60	219 "	.28 "	240	65 "	1.19 "
70	216 "	.38 "	260	41 "	1.22 "
80	211 "	.47 "	273	25 "	1.23 "
90	206 "	.55 "	280	16 "	1.24 "
100	201 "	.61 "	293	0 "	1.25 "
120	187 "	.75 "	300	-9 "	1.25 "

PJC ISSUED: 6/5/59


TEMPERATURE, °R
0
100
200
300
400
500
255
240
220
200
180
160
140
120
100
80
60
40
20
0
-10
1.27
1.2
1.1
1.0
.9
.8
.7
.6
.5
.4
.3
.2
.1
0
$\frac{L_{293} - L_T}{L_{293}}$ (multiply by 10^{-5})
$\frac{1}{L}\frac{dL}{dT}$, per °K (multiply by 10^{-5})
THERMAL EXPANSION
of L-NICKEL
0
50
100
150
200
250
300
TEMPERATURE, °K

THERMAL EXPANSION of L-NICKEL

(International Nickel Co. low-carbon nickel, 99.6% pure)

Source of Data: Altman, Rubin and Johnston 1954.

Table of Selected Values

Temp. °K	$\frac{L_{293} - L_T}{L_{293}}$	$\frac{1}{L}\frac{dL}{dT}$ per °K	Temp. °K	$\frac{L_{293} - L_T}{L_{293}}$	$\frac{1}{L}\frac{dL}{dT}$ per °K
0	230×10^{-5}	0	140	175×10^{-5}	0.92×10^{-5}
20	230 "	$.01 \times 10^{-5}$	160	156 "	1.01 "
30	230 "	.04 "	180	135 "	1.08 "
40	229 "	.09 "	200	113 "	1.13 "
50	228 "	.17 "	220	90 "	1.17 "
60	226 "	.27 "	240	66 "	1.21 "
70	223 "	.38 "	260	42 "	1.24 "
80	218 "	.48 "	273	25 "	1.26 "
90	213 "	.58 "	280	17 "	1.27 "
100	207 "	.66 "	293	0 "	1.28 "
120	192 "	.80 "	300	-9 "	1.29 "

RJC Issued: 6/5/59

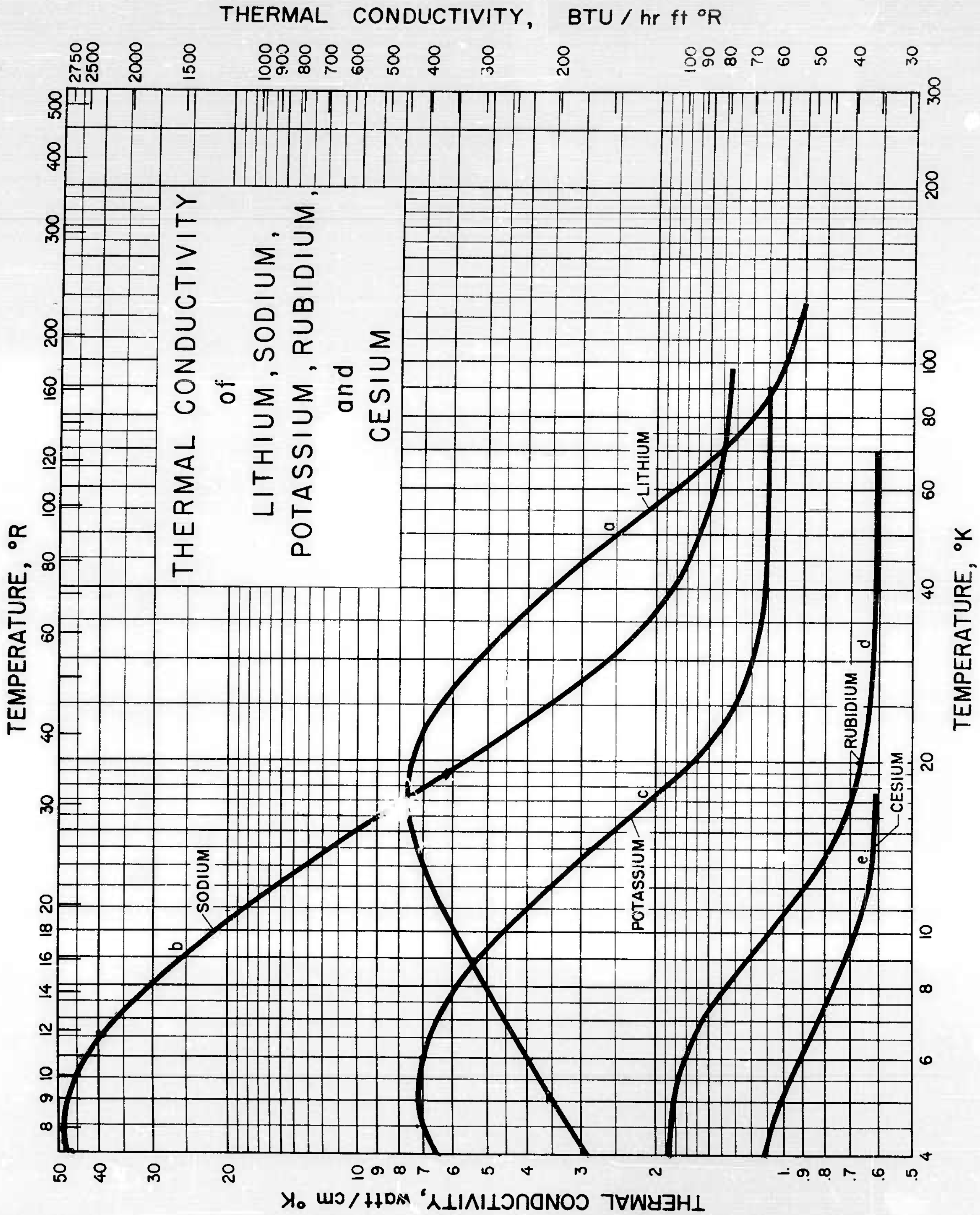
THERMAL CONDUCTIVITY of CRYOGENIC SOLIDS

CONTENTS

CONVERSION FACTORS for THERMAL CONDUCTIVITY

	$\frac{\text{Watts cm}}{\text{cm}^2\ °\text{K}}$	$\frac{\text{Watts in}}{\text{in}^2\ °\text{F}}$	$\frac{\text{Cal cm}}{\text{sec cm}^2 °\text{K}}$	$\frac{\text{BTU in}}{\text{hr ft}^2 °\text{F}}$	$\frac{\text{BTU ft}}{\text{hr ft}^2 °\text{F}}$	$\frac{\text{BTU in}}{\text{sec in}^2 °\text{F}}$	$\frac{\text{BTU in}}{\text{hr in}^2 °\text{F}}$
1 $\frac{\text{Watts cm}}{\text{cm}^2\ °\text{K}}$ =	1.000	1.411	0.2389	6.9340×10^2	57.79	1.338×10^{-3}	4.816
1 $\frac{\text{Watts in}}{\text{in}^2 °\text{F}}$ =	0.7087	1.000	0.1693	4.914×10^2	40.95	9.480×10^{-4}	3.413
1 $\frac{\text{Cal. cm}}{\text{sec cm}^2 °\text{K}}$ =	4.1858	5.907	1.000	2.9027×10^3	2.419×10^2	5.602×10^{-3}	20.16
1 $\frac{\text{BTU in}}{\text{hr ft}^2 °\text{F}}$ =	1.442×10^{-3}	2.035×10^{-3}	3.445×10^{-4}	1.000	8.33×10^{-2}	1.929×10^{-6}	6.944×10^{-3}
1 $\frac{\text{BTU ft}}{\text{hr ft}^2 °\text{F}}$ =	1.730×10^{-2}	2.442×10^{-2}	4.135×10^{-3}	12.000	1.000	2.315×10^{-5}	8.333×10^{-2}
1 $\frac{\text{BTU in}}{\text{sec in}^2 °\text{F}}$ =	7.4738×10^2	1.0548×10^3	1.785×10^2	5.184×10^5	4.3191×10^4	1.000	3.600×10^3
1 $\frac{\text{BTU in}}{\text{hr in}^2 °\text{F}}$ =	0.2076	0.2930	4.960×10^{-2}	1.44×10^2	12.000	2.778×10^{-4}	1.000

JRC/VJJ Issued: 10/7/59
Revised: 5/20/60


THERMAL CONDUCTIVITY of LITHIUM, SODIUM, POTASSIUM, RUBIDIUM, and CESIUM
THERMAL CONDUCTIVITY, BTU / hr ft °R
2750 2500 2000 1500 1000 900 800 700 600 500 400 300 200 100 90 80 70 60 50 40 30
TEMPERATURE, °R
8 9 10 12 14 16 18 20 30 40 60 80 100 120 160 200 300 400 500
TEMPERATURE, °K
4 6 8 10 20 40 60 80 100 200 300
THERMAL CONDUCTIVITY, watt/cm °K
50 40 30 20 10 9 8 7 6 5 4 3 2 1 .9 .8 .7 .6 .5
LITHIUM
a
SODIUM
b
POTASSIUM
c
RUBIDIUM
d
CESIUM
e

THERMAL CONDUCTIVITY OF LITHIUM, SODIUM POTASSIUM, RUBIDIUM, and CESIUM

Source of Data:

(a) D.K.C. MacDonald, G.K. White and S.B. Woods, Proc. Roy. Soc. (London) A235, 358-374 (1956).

(b) Same as (a); and R. Berman and D.K.C. MacDonald, Proc. Roy. Soc. (London) A209, 368-375 (1951).

(c) Same as (a).

(d) Same as (a).

(e) Same as (a).

Comments:

(a) Lithium; "high purity," melted and extruded into a stainless steel tube, (A.D. Mackay)

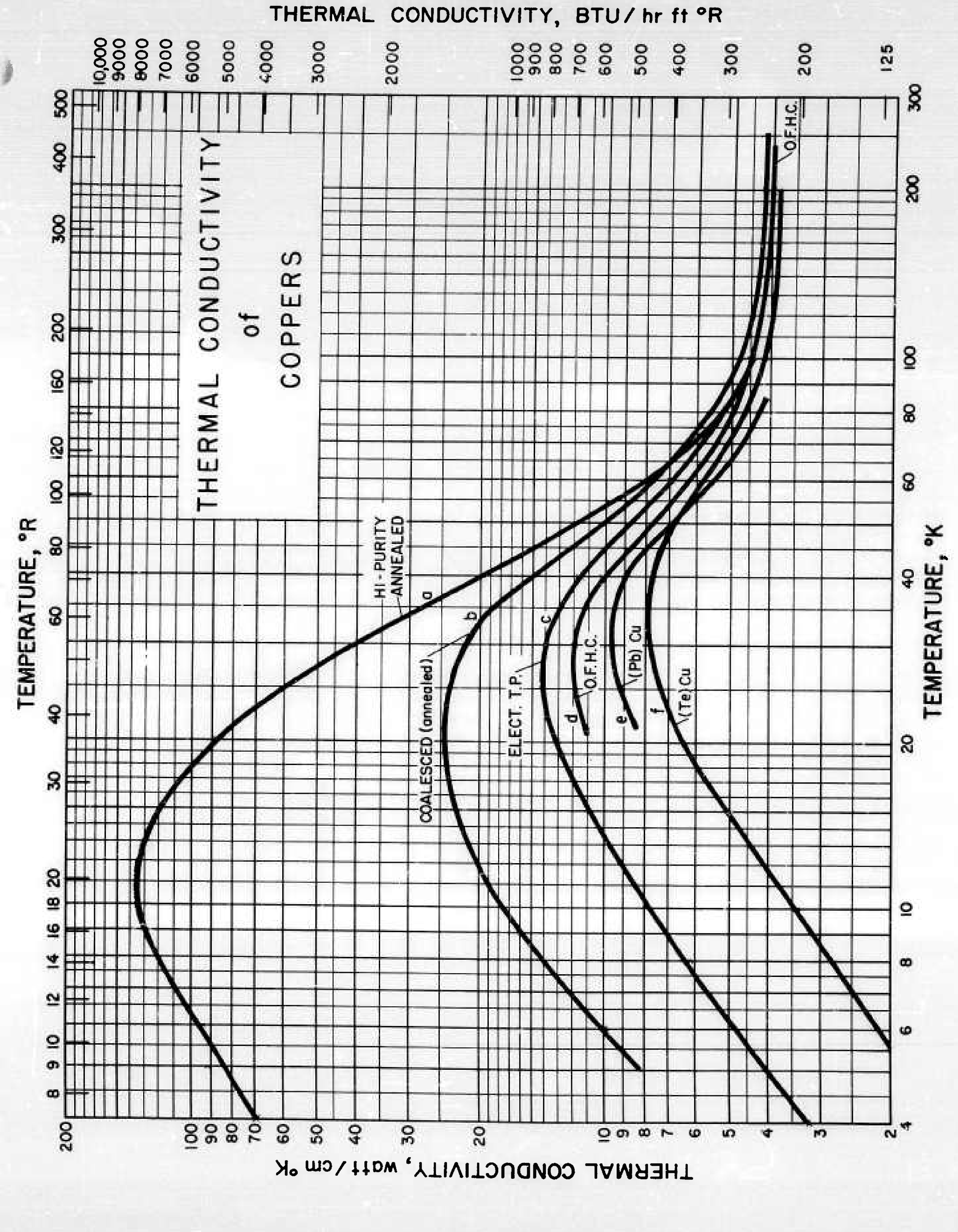
(b) Sodium; "exceptional purity" melted in vacuum and cast in glass, (Philips); and trace of silver, melted in vacuum and cast in glass, (Philips)

(c) Potassium; "high purity," melted in vacuum and cast in glass

(d) Rubidium; "high purity," melted in vacuum and cast in glass, (Mackay)

(e) Cesium; "high purity," melted in vacuum and cast in glass, (Mackay)

RLP Issued: 5/1/58
Revised: 3/1/59


THERMAL CONDUCTIVITY, BTU/ hr ft °R
THERMAL CONDUCTIVITY of COPPERS
TEMPERATURE, °R
TEMPERATURE, °K
THERMAL CONDUCTIVITY, watt/cm °K
HI-PURITY ANNEALED
COALESCED (annealed)
ELECT. T.P.
O.F.H.C.
(Pb) Cu
(Te) Cu
a
b
c
d
e
f

THERMAL CONDUCTIVITY of COPPERS

Source of Data:

(a) R. L. Powell, H. M. Roder and W. J. Hall, to be published

(b) R. L. Powell, H. M. Roder and W. M. Rogers, J. Appl. Phys. 28, 1282-1288 (1957)

(c) Same as (b).

(d) R. W. Powers, D. Schwartz and H. L. Johnston, TR 264-5, Cryogenics Laboratory, Ohio State University (1951) 11 pp.

(e) R. L. Powell and D. O. Coffin, Rev. Sci. Instr. 26, 516 (1955).

(f) Same as (b).

Comments:

(a) High Purity; 99.999% pure, annealed, (Am. Smelt Ref.)

(b) Coalesced; 99.98% pure, annealed, (Phelps Dodge)

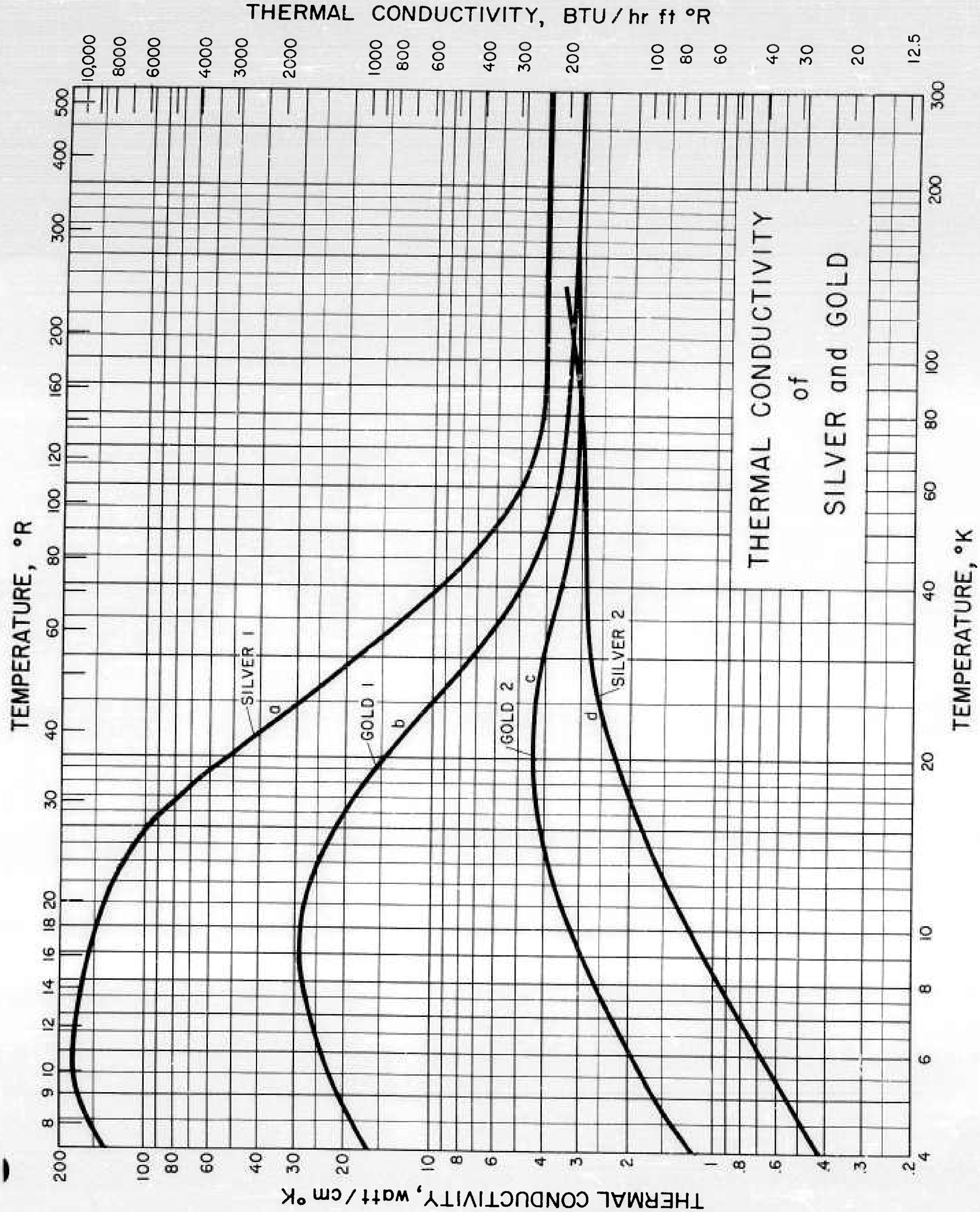
(c) Electrolytic Tough Pitch; 99.95% pure, annealed

(d) O.F.H.C.; 99.95% pure, annealed

(e) (Pb) Cu; 1% Pb, annealed

(f) (Te) Cu; 0.6% Te, annealed

RLP Issued: 5/1/58
Revised: 3/1/59

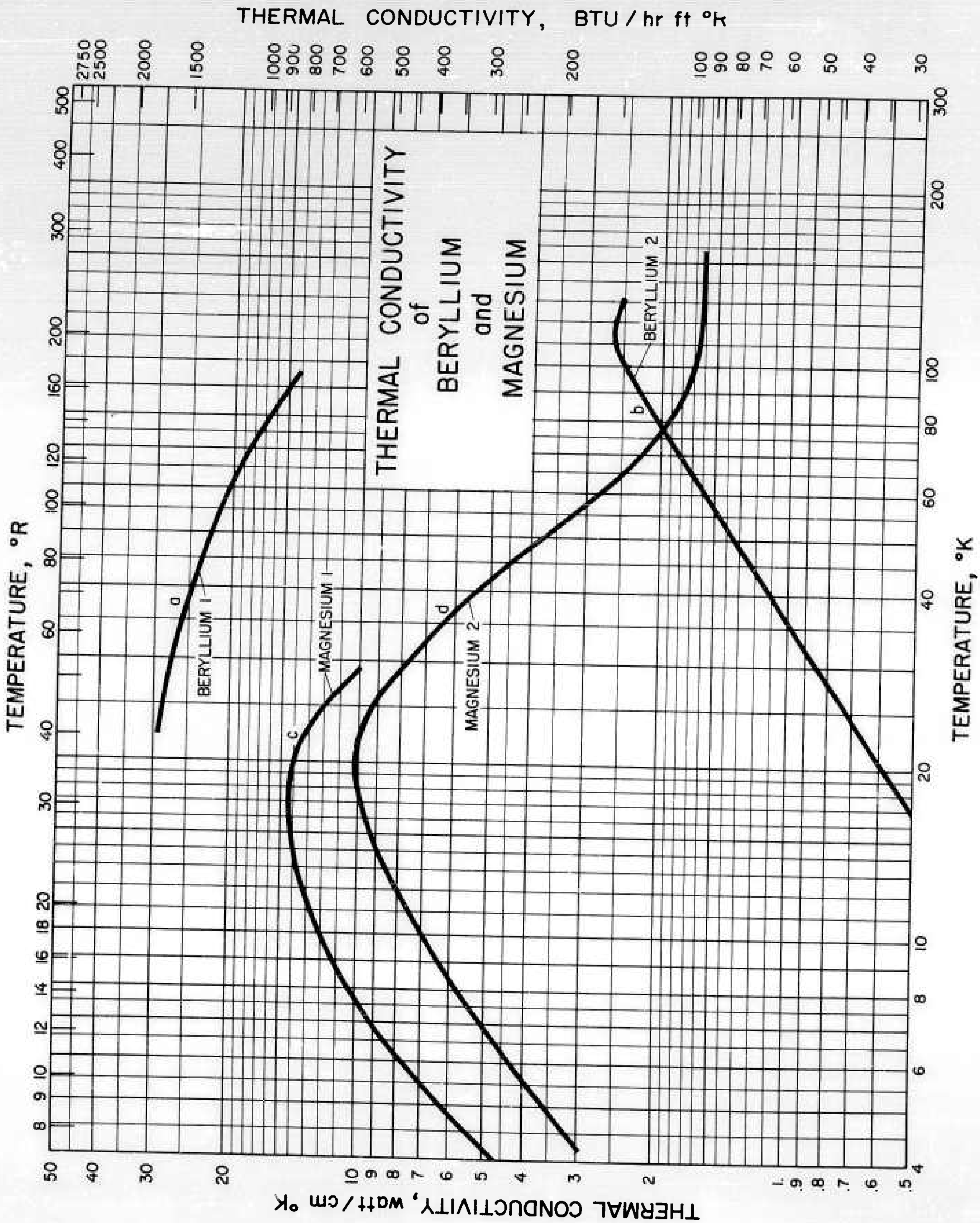

THERMAL CONDUCTIVITY of SILVER and GOLD
THERMAL CONDUCTIVITY, BTU/hr ft °R
THERMAL CONDUCTIVITY, watt/cm °K
TEMPERATURE, °R
TEMPERATURE, °K
SILVER 1
a
GOLD 1
b
GOLD 2
c
SILVER 2
d
10,000
8000
6000
4000
3000
2000
1000
800
600
400
300
200
100
80
60
40
30
20
12.5
500
400
300
200
160
120
100
80
60
40
30
20
18
16
14
12
10
9
8
200
100
80
60
40
30
20
10
8
6
4
3
2
1
.8
.6
.4
.3
.24
300
200
100
80
60
40
20
10
8
6
4

THERMAL CONDUCTIVITY
of SILVER and GOLD

Source of Data:
(a) G. K. White, Proc. Phys. Soc. (London) A66, 844-845 (1953); C. H. Lees, Phil. Trans. Roy. Soc. (London) A208, 381-443 (1908)
(b) G. K. White, Ibid. (a)
(c) G. K. White, Proc. Phys. Soc. (London) A66, 559-564 (1953); W. Meissner, Ann. Physik 47, 1001-1058 (1915)
(d) G. K. White, Ibid. (c)

Comments:
(a) Silver 1; 99.999% pure, annealed, and 99.9% pure (Johnson, Matthey)
(b) Silver 2; 99.999% pure, drawn (Johnson, Matthey)
(c) Gold 1; 99.999% pure, annealed (Johnson, Matthey), 99.999% pure, annealed (Mylius)
(d) Gold 2; 99.9% pure, drawn, (Garrett)

RLP Issued: 5/1/58
Revised: 3/1/59


THERMAL CONDUCTIVITY, BTU / hr ft °K
THERMAL CONDUCTIVITY of BERYLLIUM and MAGNESIUM
BERYLLIUM 1
BERYLLIUM 2
MAGNESIUM 1
MAGNESIUM 2
a
b
c
d
TEMPERATURE, °R
TEMPERATURE, °K
THERMAL CONDUCTIVITY, watt / cm °K

THERMAL CONDUCTIVITY of BERYLLIUM and MAGNESIUM

Source of Data:

(a) H.-D. Erfling and E. Gruneisen, Ann. Physik 41, 89-99 (1942).

(b) G.K. White and S.B. Woods, Can. J. Physics 33, 58-73 (1955).

(c) W.R.G. Kemp, A.K. Sreedhar and G.K. White, Proc. Phys. Soc. (London) A66, 1077-1078 (1953).

(d) Same as (c)

Comments:

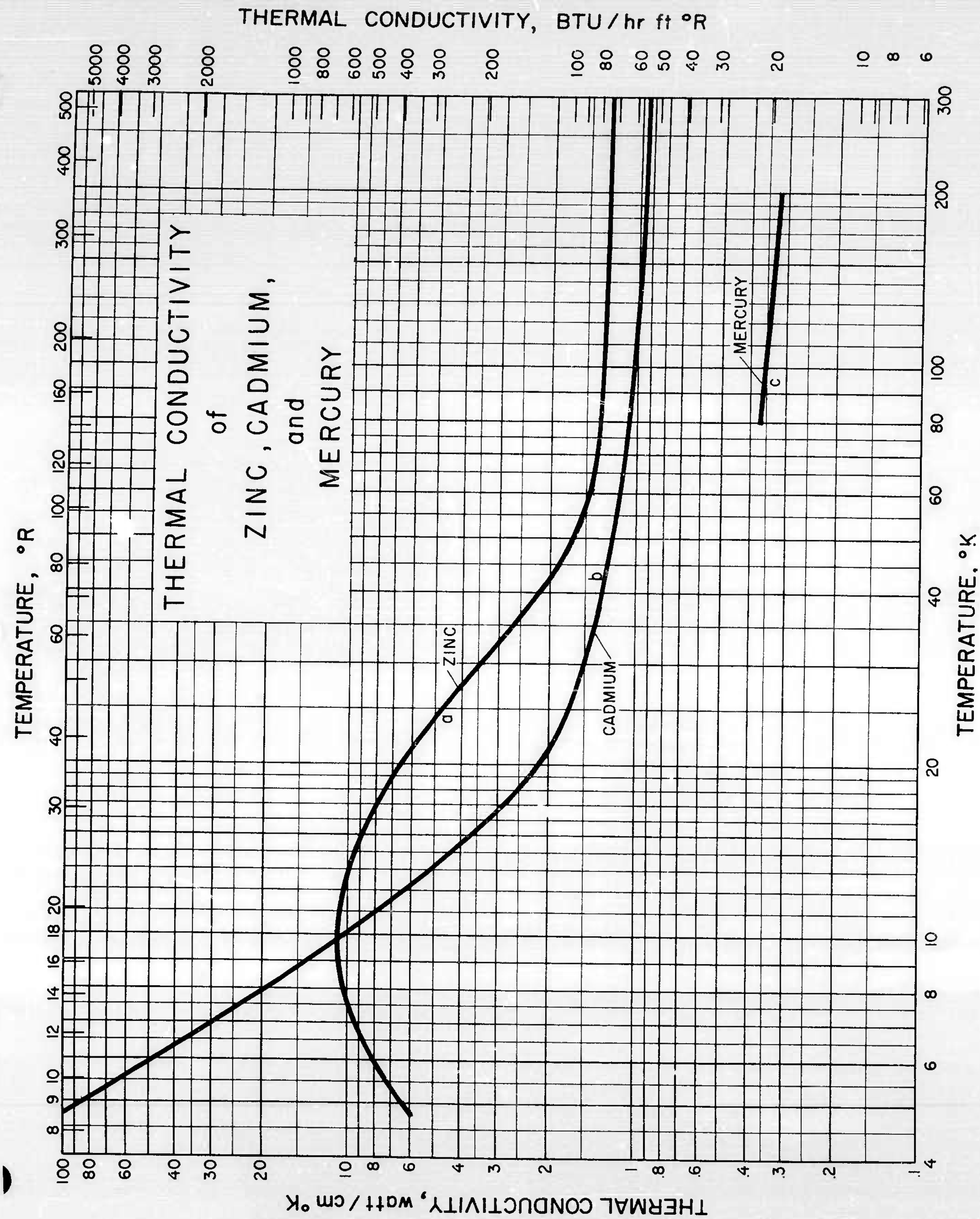
(a) Beryllium-1; "high Purity" single crystal, (Degussa)

(b) Beryllium-2; 2% magnesium, sintered rod, (Brush)

(c) Magnesium-1; 99.98% pure, annealed in vacum 3 hours at 350°C, (Johnson, Matthey)

(d) Magnesium-2; 99.98% pure, cold drawn, (Johnson, Matthey)

RLP Issued: 5/1/58
Revised: 3/1/59



THERMAL CONDUCTIVITY, BTU/hr ft °R
THERMAL CONDUCTIVITY of ZINC, CADMIUM, and MERCURY
ZINC
a
CADMIUM
b
MERCURY
c
TEMPERATURE, °R
TEMPERATURE, °K
THERMAL CONDUCTIVITY, watt/cm °K

THERMAL CONDUCTIVITY of ZINC, CADMIUM, and MERCURY

Source of Data: (a) H. M. Rosenberg, Phil. Trans. Roy Soc. (London) A247, 441-497 (1955); C. C. Bidwell and E. J. Lewis, Phys. Rev. 33, 249-251 (1929).

(b) H. M. Rosenberg, Phil. Trans. Roy. Soc. (London) A247, 441-497 (1955); E. Goens and E. Gruneisen, Ann. Physik 14, 164-180 (1932).

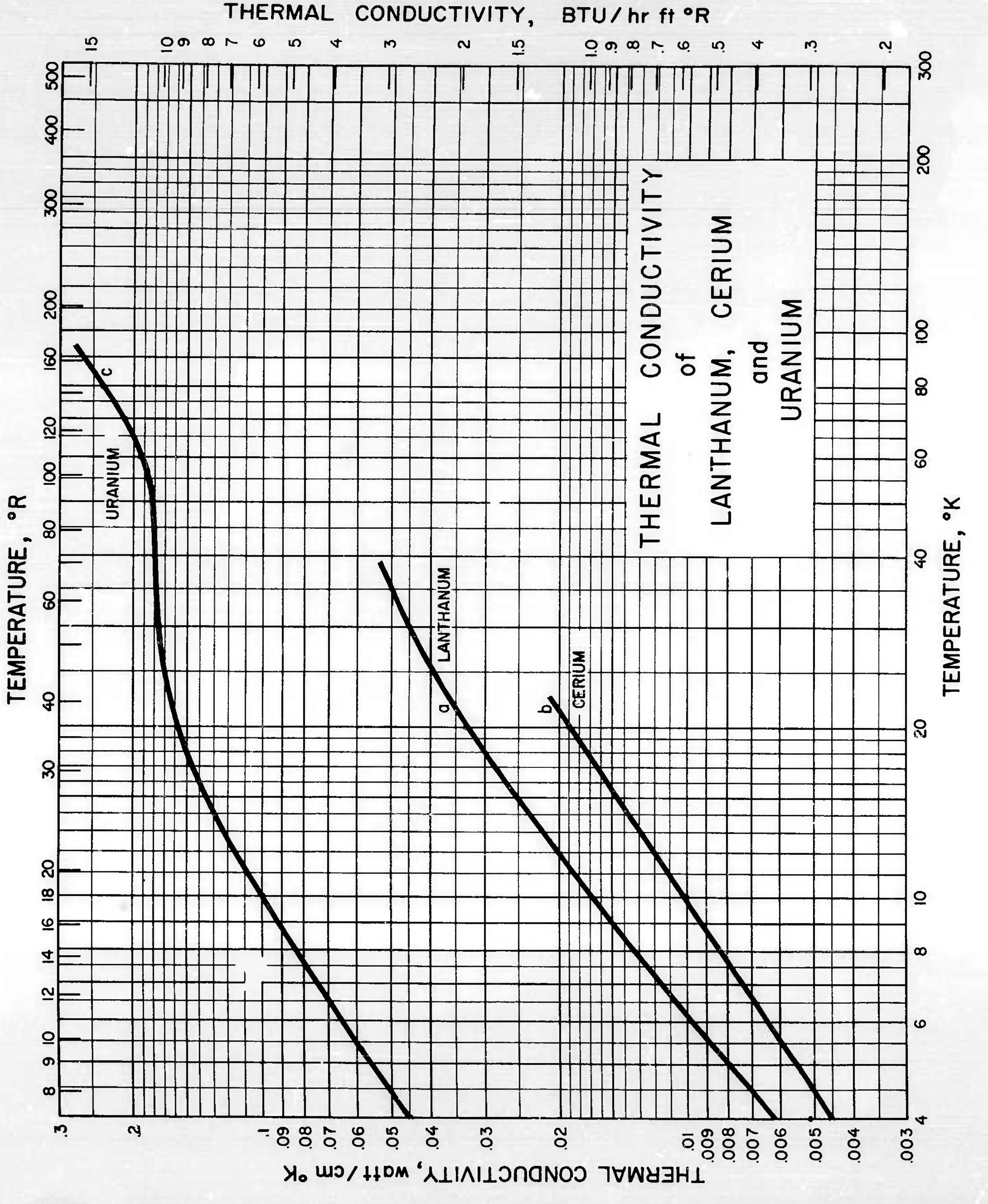
(c) H. Reddemann, Ann. Physik 14, 139-163 (1932).

Comments: (a) Zinc; 99.997% pure, single crystal, annealed, (Imperial Smelt); and 99.993 pure, single crystal

(b) Cadmium; 99.995% pure, single crystal, (Hilger); and "pure" single crystal, (Kahlbaum)

(c) Mercury; Average values for ten single crystals

RLP Issued: 5/1/58
Revised: 3/1/59


THERMAL CONDUCTIVITY of LANTHANUM, CERIUM and URANIUM
THERMAL CONDUCTIVITY, BTU/hr ft °R
THERMAL CONDUCTIVITY, watt/cm °K
TEMPERATURE, °R
TEMPERATURE, °K
URANIUM
LANTHANUM
CERIUM
a
b
c

THERMAL CONDUCTIVITY of LANTHANUM, CERIUM, and URANIUM

Source of Data: (a) H.M. Rosenberg, Phil. Trans. Roy. Soc. (London) A247, 441-497 (1955).

(b) Same as (a).

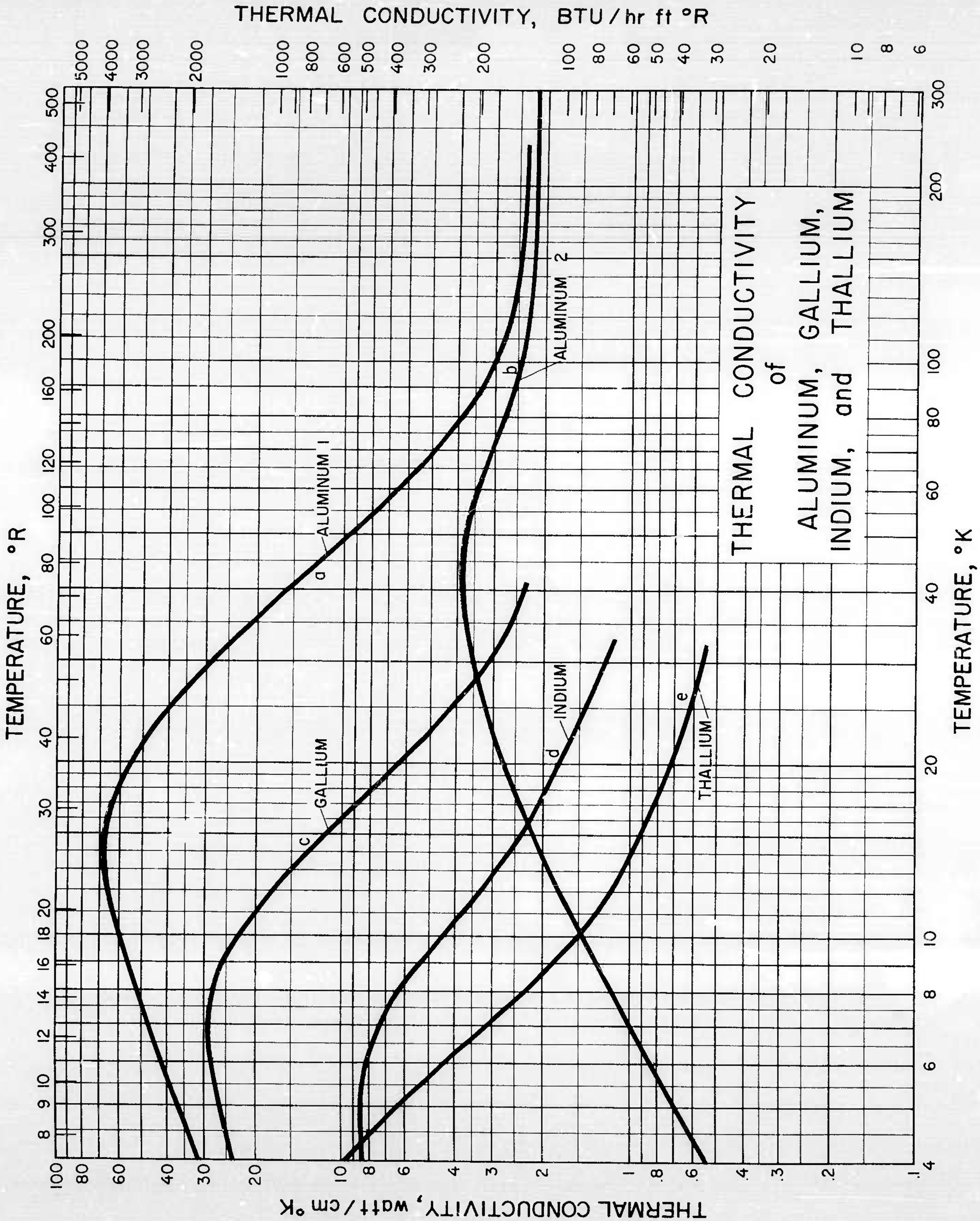
(c) Same as (a).

Comments: (a) Lanthanum; 99.94% pure

(b) Cerium; 99.6% pure

(c) Uranium; "Very high" purity

RLP Issued: 5/1/58
Revised: 3/1/59


THERMAL CONDUCTIVITY, BTU/hr ft °R
THERMAL CONDUCTIVITY of ALUMINUM, GALLIUM, INDIUM, and THALLIUM
ALUMINUM 1
ALUMINUM 2
GALLIUM
INDIUM
THALLIUM
a
b
c
d
e
TEMPERATURE, °R
TEMPERATURE, °K
THERMAL CONDUCTIVITY, watt/cm °K

THERMAL CONDUCTIVITY of ALUMINUM, GALLIUM, INDIUM, and THALLIUM

Source of Data: (a) R. A. Andrews, R. T. Webber and D. A. Spohr, Phys. Rev. 84, 994-996 (1951); R. W. Powers, D. Schwartz, and H. L. Johnston, TR 264-5, Cryogenic Laboratory, Ohio State University 11 pp (1951).

(b) R. L. Powell, W. J. Hall and H. M. Roder, to be published.

(c) H. M. Rosenberg, Phil. Trans. Roy. Soc. (London) A247, 441-497 (1955).

(d) Same as (c)

(e) Same as (c)

Comments: (a) Aluminum-1; 99.996% pure, single crystal (Alcoa) and 99.99% pure, cold drawn (Alcoa)

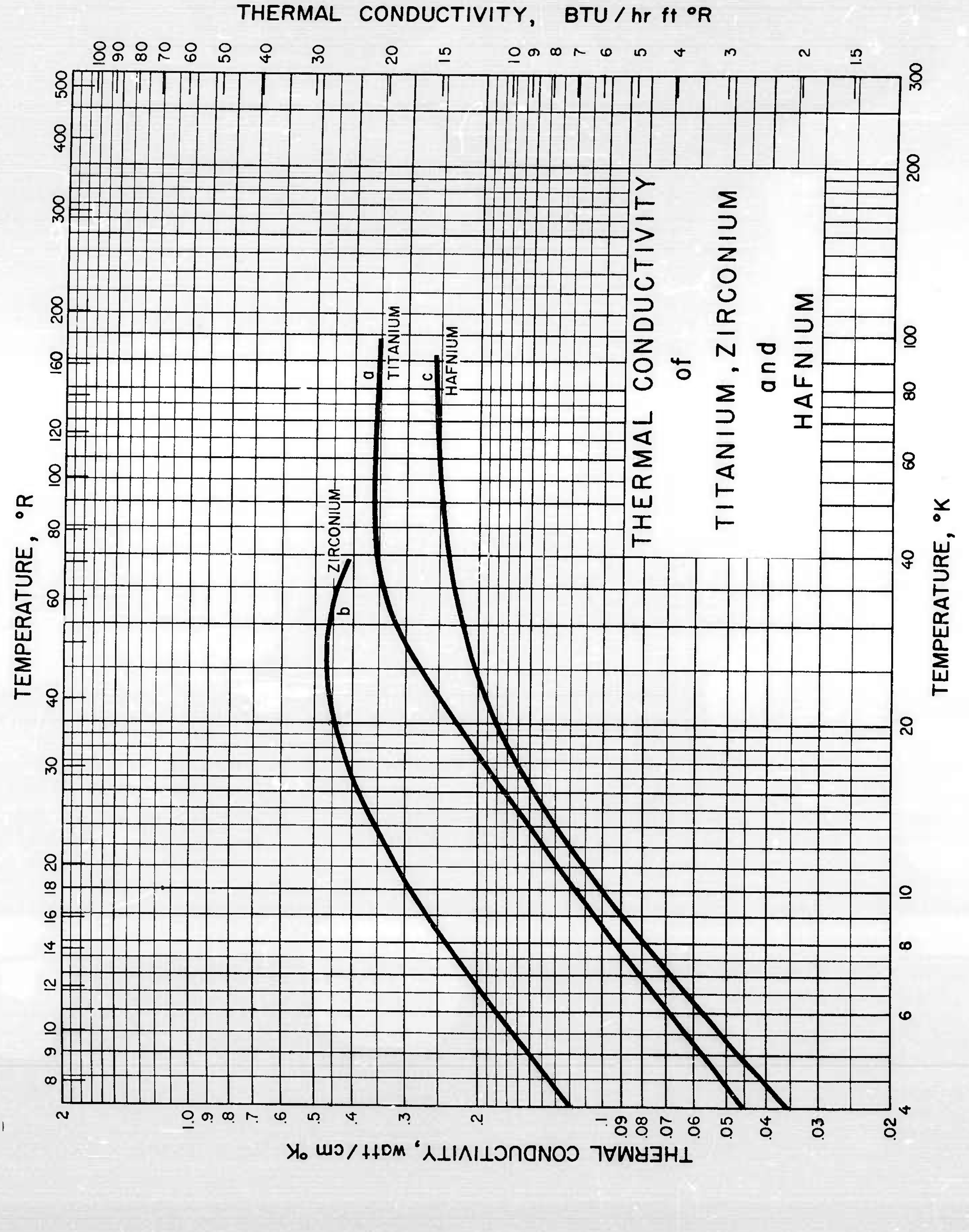
(b) Aluminum-2; 99% commercial pure, (Alcoa) **drawn**

(c) Gallium; Single crystal

(d) Indium; 99.993% pure, (Johnson, Matthey)

(e) Thallium; 99.99% pure, (Johnson, Matthey)

RLP Issued: 5/1/58
Revised: 3/1/59


THERMAL CONDUCTIVITY, BTU / hr ft °R
THERMAL CONDUCTIVITY of TITANIUM, ZIRCONIUM and HAFNIUM
TITANIUM
ZIRCONIUM
HAFNIUM
a
b
c
TEMPERATURE, °R
TEMPERATURE, °K
THERMAL CONDUCTIVITY, watt/cm °K

THERMAL CONDUCTIVITY of TITANIUM, ZIRCONIUM, and HAFNIUM

Source of Data: (a) H.M. Rosenberg, Phil. Trans. Roy. Soc. (London) A247, 441-497 (1955)

(b) Same as (a)

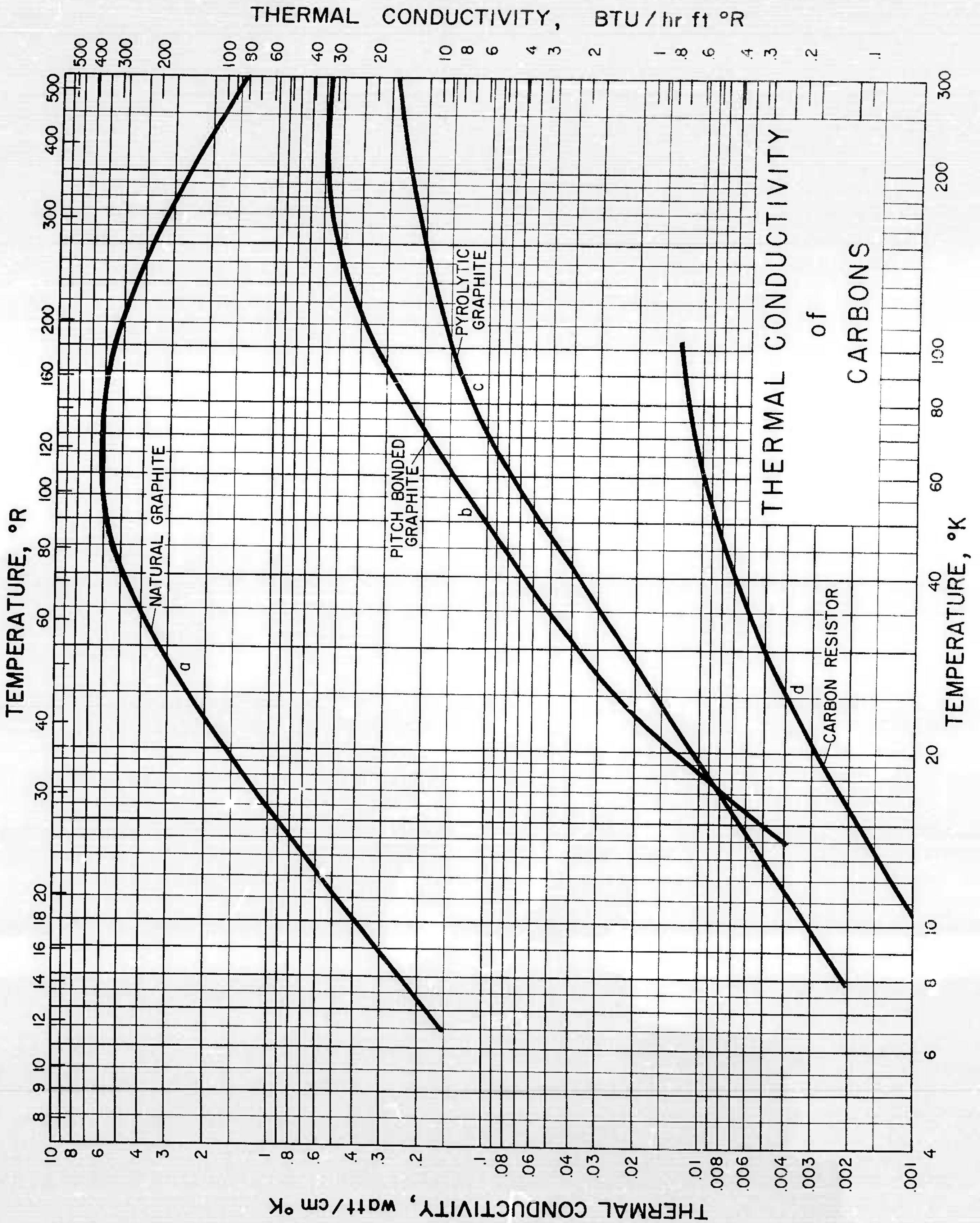
(c) G.K. White and S.B. Woods, Can. J. Physics 35, 892-900 (1957)

Comments: (a) Titanium; 99.99% pure, (Assoc. Elec. Industries) single crystal

(b) Zirconium; 98% pure, (Metropolitan Vickers)

(c) Hafnium: 1% Zr., (Foote Mineral)

RLP Issued: 5/1/58
Revised: 3/1/59


THERMAL CONDUCTIVITY of CARBONS
THERMAL CONDUCTIVITY, BTU / hr ft °R
THERMAL CONDUCTIVITY, watt/cm °K
TEMPERATURE, °R
TEMPERATURE, °K
NATURAL GRAPHITE
PITCH BONDED GRAPHITE
PYROLYTIC GRAPHITE
CARBON RESISTOR
a
b
c
d

THERMAL CONDUCTIVITY of CARBONS

Source of Data: (a) W.W. Smith and N.S. Rasor, Phys. Rev. 104, 885 (1956)

(b) Same as (a)

(c) Same as (a)

(d) R. Berman, Bull. Inst. Int. du Froid, Annexe 1952-1 (1952)

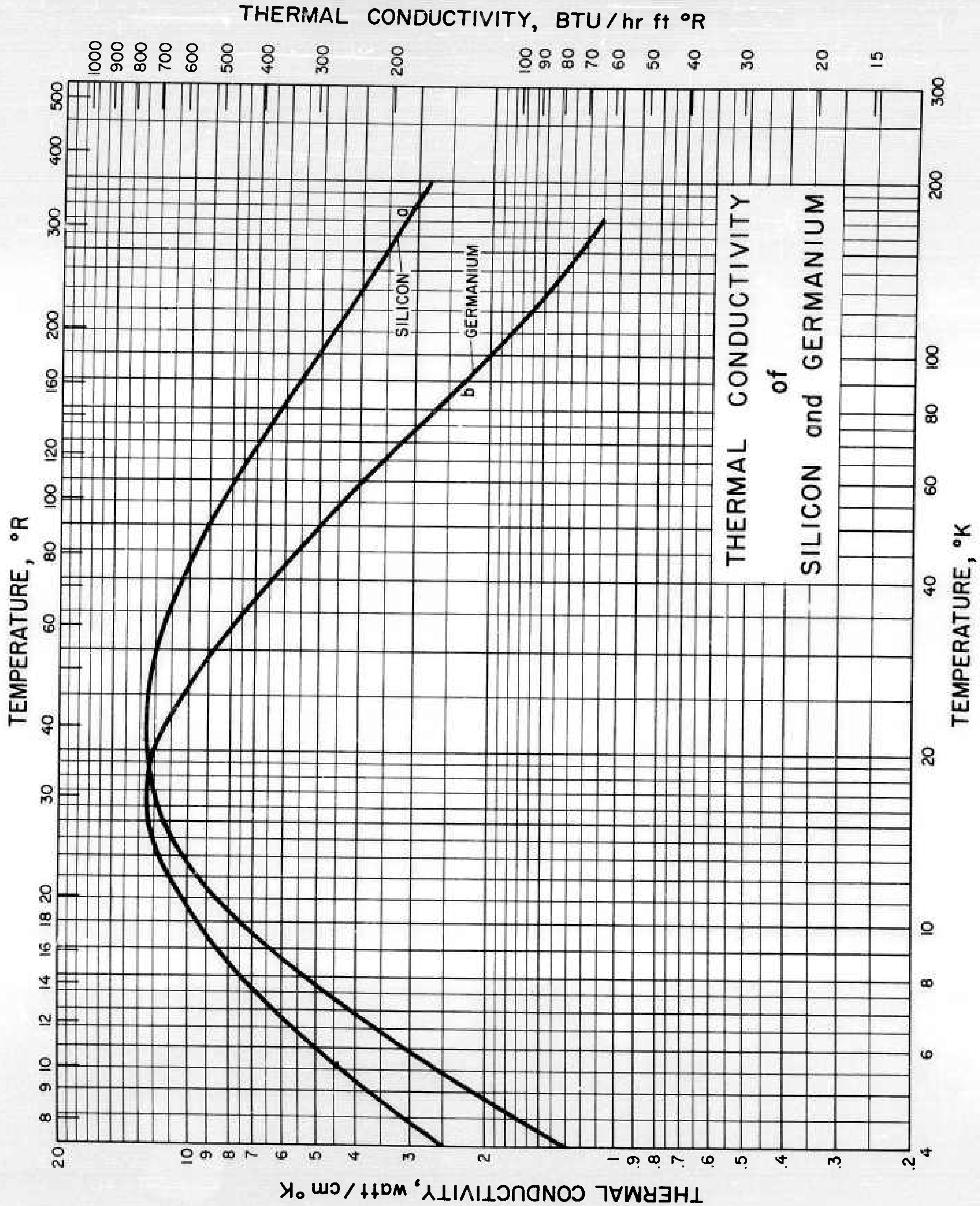
Comments: (a) Natural Graphite: National Carbon

(b) Pitch Bonded Graphite; Type AGOT-KC

(c) Pyrolytic Graphite; National Carbon

(d) Carbon Resistor;

RLP Issued: 5/1/58
Revised: 3/1/59


THERMAL CONDUCTIVITY, BTU/hr ft °R
THERMAL CONDUCTIVITY of SILICON and GERMANIUM
SILICON
a
GERMANIUM
b
TEMPERATURE, °R
TEMPERATURE, °K
THERMAL CONDUCTIVITY, watt/cm °K

THERMAL CONDUCTIVITY of
SILICON and GERMANIUM

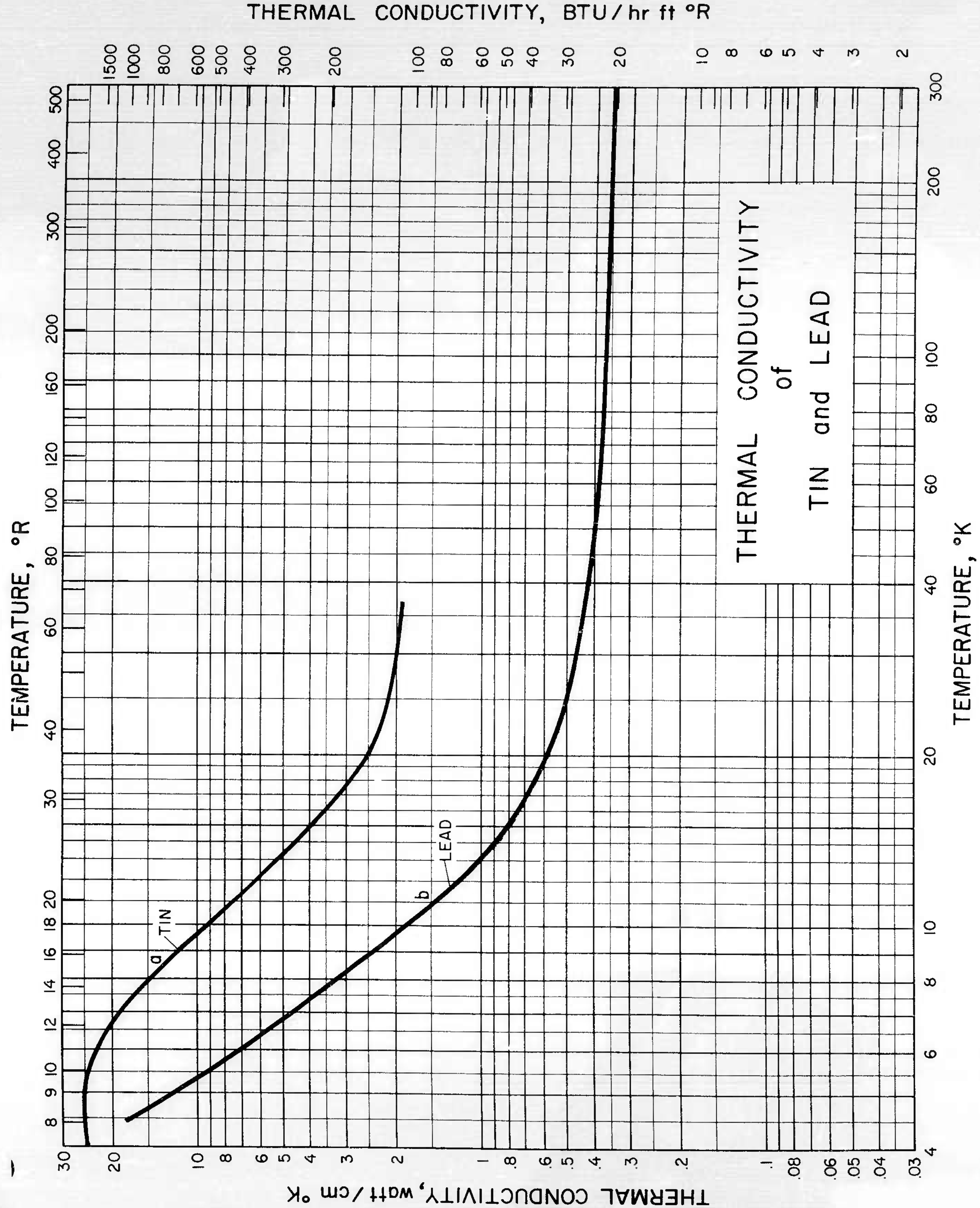
Source of Data: (a) G.K. White and S.B. Woods, Phys. Rev. 103, 569-571 (1956)

(b) Same as (a)

Comments: (a) Silicon; n-type single crystal

(b) Germanium; p-type

RLP Issued: 5/1/58
Revised: 3/1/59


THERMAL CONDUCTIVITY, BTU/hr ft °R
THERMAL CONDUCTIVITY of TIN and LEAD
TEMPERATURE, °R
TEMPERATURE, °K
THERMAL CONDUCTIVITY, watt/cm °K
a TIN
b LEAD

THERMAL CONDUCTIVITY
of TIN and LEAD

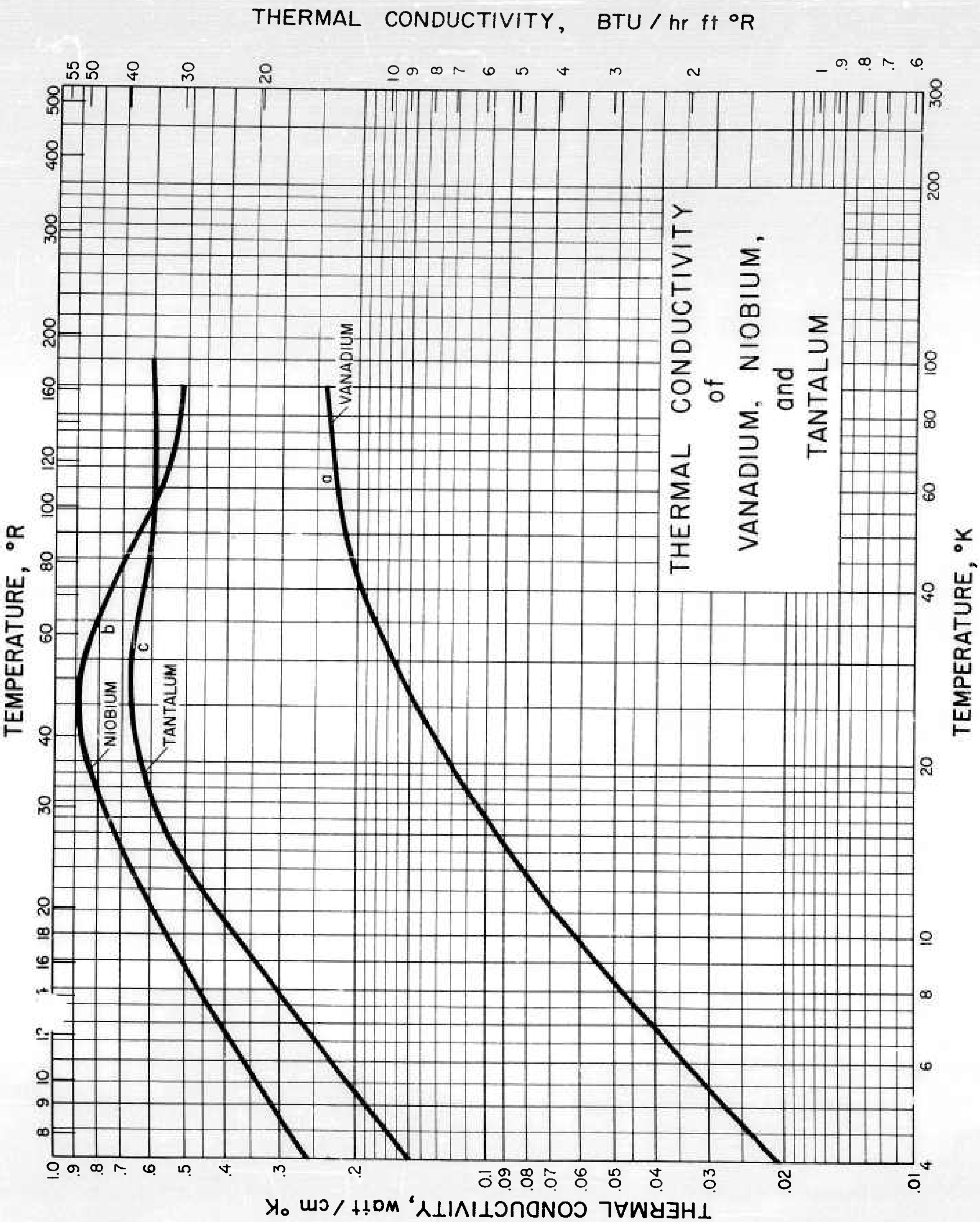
Source of Data: (a) H.M. Rosenberg, Phil.Trans. Roy. Soc. (London) A247, 441-497 (1955)

(b) Same as (a) and W. Meissner, Ann. Physik 47, 1001-1058 (1915)

Comments: (a) Tin; 99.995% pure, single crystal, (Johnson, Matthey)

(b) Lead; 99.998% pure, single crystal (Tadanac) and 99.998% pure, cold drawn, (Kahlbaum)

RLP Issued: 5/1/58
Revised: 3/1/59


THERMAL CONDUCTIVITY, BTU / hr ft °R
THERMAL CONDUCTIVITY of VANADIUM, NIOBIUM, and TANTALUM
TEMPERATURE, °R
TEMPERATURE, °K
THERMAL CONDUCTIVITY, watt / cm °K
VANADIUM
NIOBIUM
TANTALUM
a
b
c

THERMAL CONDUCTIVITY of
VANADIUM, NIOBIUM, and TANTALUM

Source of Data: (a) G. K. White and S. B. Woods, Can. J. Physics 35, 892-900 (1957)

(b) Same as (a)

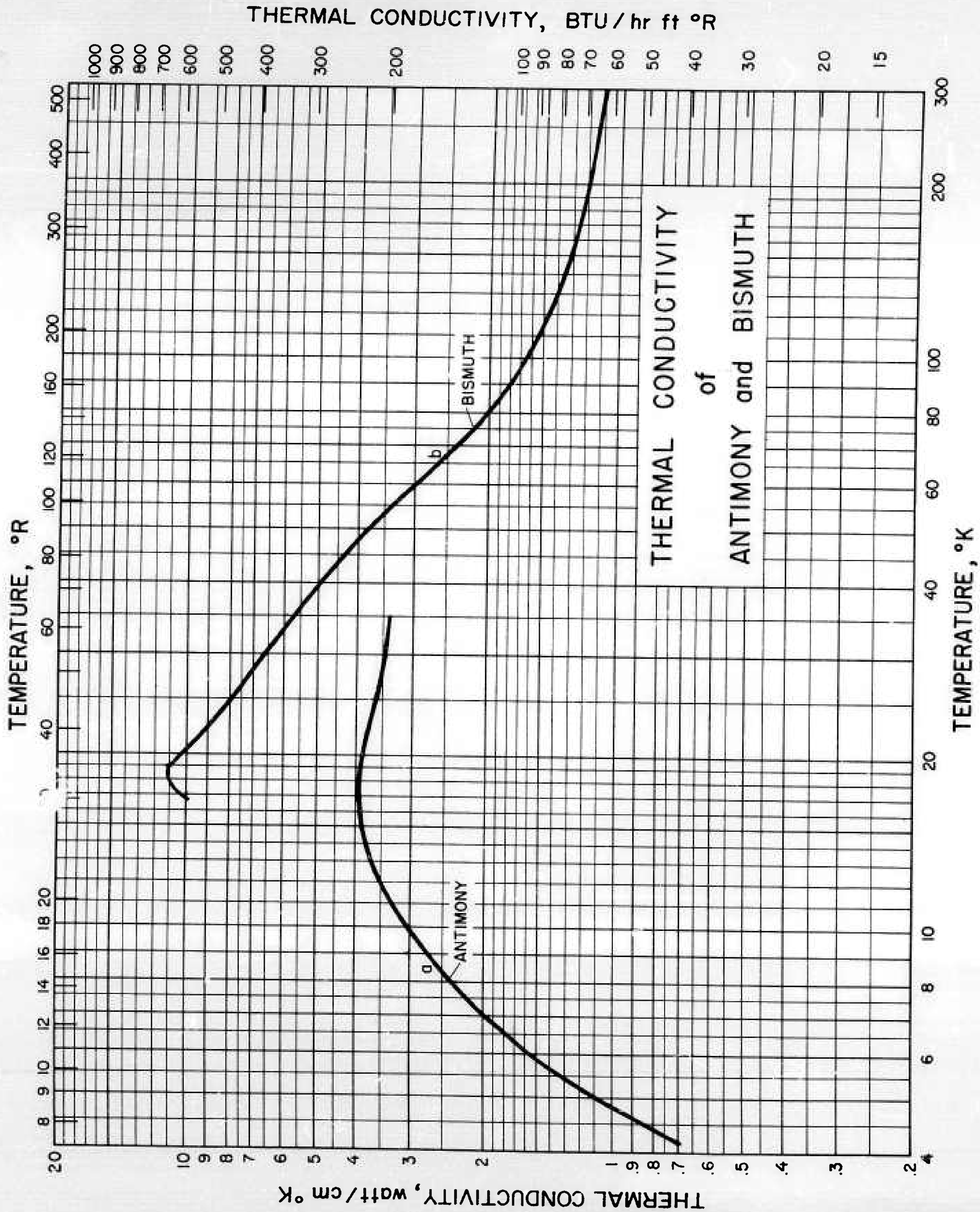
(c) H. M. Rosenberg, Phil. Trans. Roy. Soc. (London) A247, 441-497 (1955)

Comments: (a) Vanadium; 99.9% pure, (Electrometallurgical Co.)

(b) Niobium; 99.9% pure, annealed in vacuum, (Fansteel Metal)

(c) Tantalum; 99.98% pure, (Johnson, Matthey)

RLP Issued: 5/1/58
Revised: 3/1/59

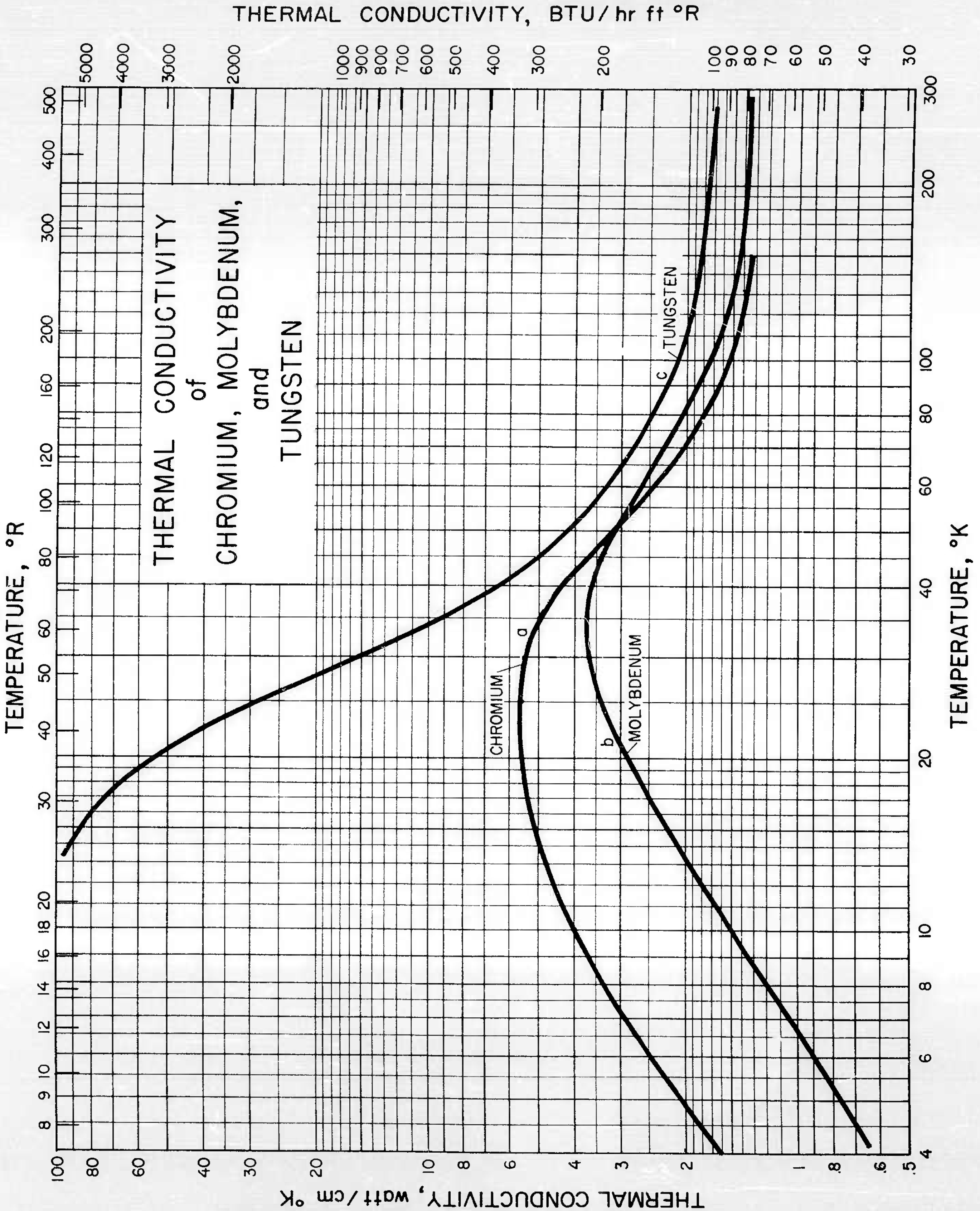

THERMAL CONDUCTIVITY, BTU/hr ft °R
THERMAL CONDUCTIVITY of ANTIMONY and BISMUTH
BISMUTH
b
ANTIMONY
a
TEMPERATURE, °R
TEMPERATURE, °K
THERMAL CONDUCTIVITY, watt/cm °K

THERMAL CONDUCTIVITY of ANTIMONY and BISMUTH

Source of Data: (a) H. M. Rosenberg, Phil. Trans. Roy. Soc. (London) A247, 441-497 (1955)
A. Eucken and G. Gelhoff, Deutsch Physik Gesell, 14, 169-182 (1912)
(b) W. J. deHaas and W. J. Capel, Physica 1, 929-934 (1934)
H. Reddemann, Ann. Physik 20, 441-448 (1934)

Comments: (a) Antimony; annealed, (Johnson, Matthey)
cold drawn (Kahlbaum)
(b) Bismuth; 99.995% pure, single crystal, (Hilger)
single crystal, (Kahlbaum)

RLP Issued: 5/1/58
Revised: 3/1/59


THERMAL CONDUCTIVITY, BTU/hr ft °R
THERMAL CONDUCTIVITY of CHROMIUM, MOLYBDENUM, and TUNGSTEN
TEMPERATURE, °R
TEMPERATURE, °K
THERMAL CONDUCTIVITY, watt/cm °K
a CHROMIUM
b MOLYBDENUM
c TUNGSTEN

THERMAL CONDUCTIVITY OF CHROMIUM, MOLYBDENUM, and TUNGSTEN

Source of Data: (a) A.F.A. Harper, W.R.G. Kemp, P.G. Klemens, R.J. Tainsh, and G.K. White, Phil. Mag. 2, 577-583 (1957).

(b). H.M. Rosenberg, Phil. Trans. Roy. Soc. (London) A247, 441-497 (1955); W.G. Kannaluik, Proc. Roy. Soc. (London) A141, 159-168 (1933)

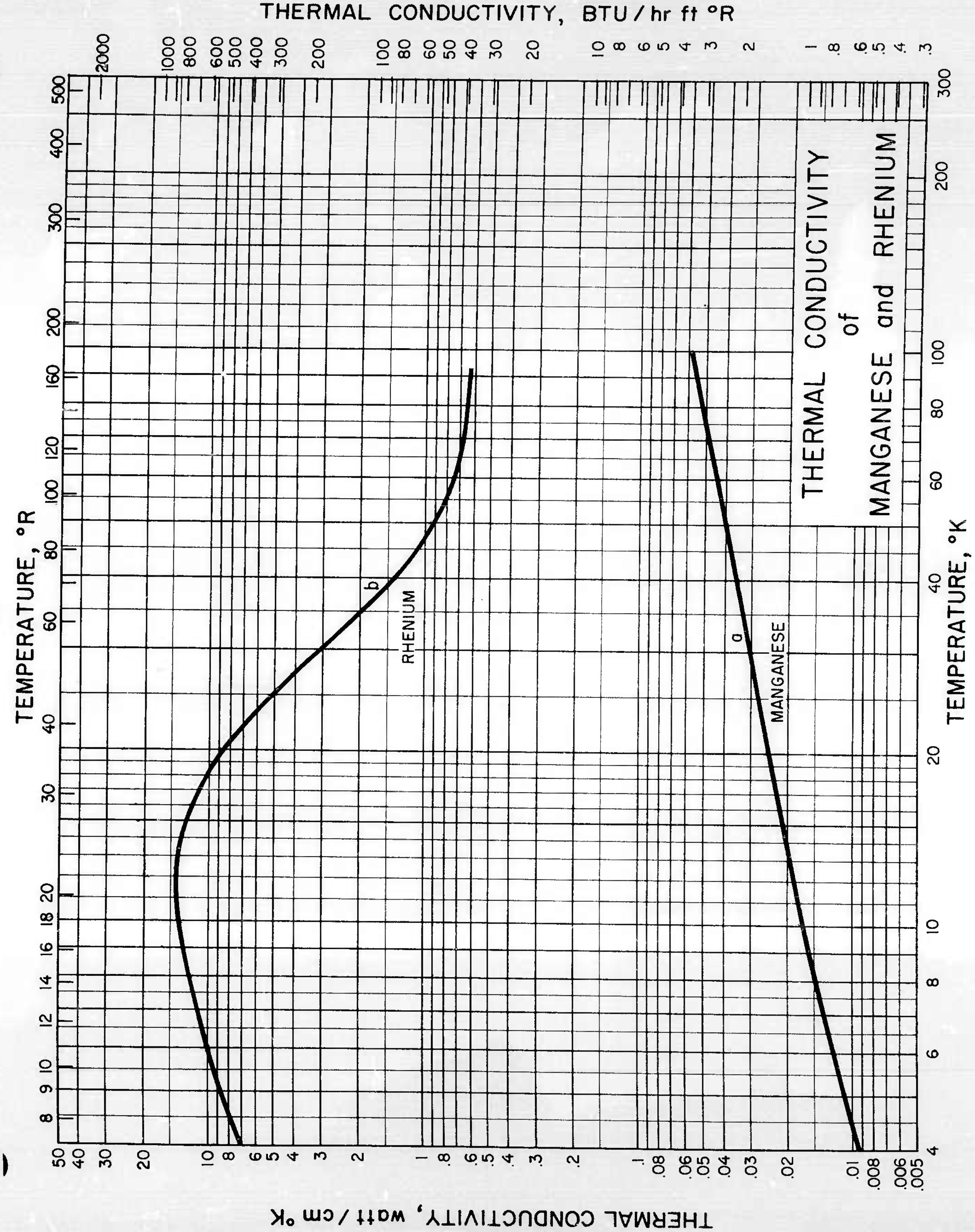
(c). W.J. deHaas and J. deNobel, Physica 5, 449-463 (1938)

Comments: (a) Chromium; 99.998% pure, recrystallized.

(b) Molybdenum; 99.95% pure and 99.8% pure

(c) Tungsten; Philips, single crystal

RLP Issued: 5/1/58
Revised: 3/1/59


THERMAL CONDUCTIVITY, BTU / hr ft °R
THERMAL CONDUCTIVITY, watt / cm °K
TEMPERATURE, °R
TEMPERATURE, °K
THERMAL CONDUCTIVITY of MANGANESE and RHENIUM
RHENIUM
b
MANGANESE
a

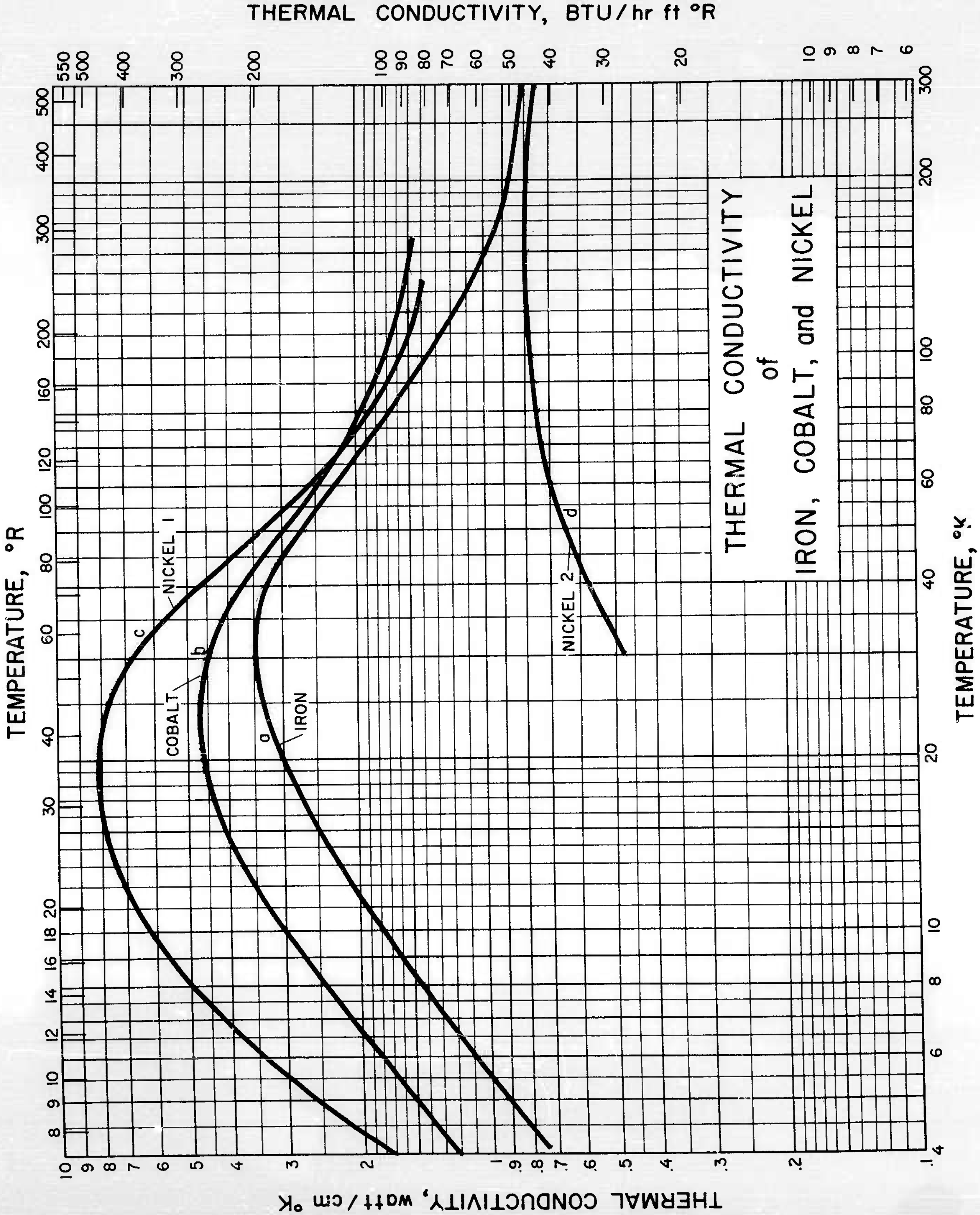
THERMAL CONDUCTIVITY of MANGANESE and RHENIUM

Source of Data: (a) G. K. White and S. B. Woods, Can J. Physics 35, 346-348 (1957)
(b) G. K. White and S. B. Woods, Can J. Physics 35, 656-665 (1957)

Comments: (a) Manganese; 99.99% pure, α phase, annealed, (Johnson, Matthey)
(b) Rhenium; 99.99% pure, zone melted.

RLP Issued: 5/1/58
Revised: 3/1/59

3.181



THERMAL CONDUCTIVITY, BTU/hr ft °R
THERMAL CONDUCTIVITY of IRON, COBALT, and NICKEL
TEMPERATURE, °R
TEMPERATURE, °K
THERMAL CONDUCTIVITY, watt/cm °K
NICKEL 1
NICKEL 2
COBALT
IRON
a
b
c
d

THERMAL CONDUCTIVITY of IRON, COBALT, and NICKEL

Source of Data:

(a) H.M. Rosenberg, Phil. Trans. Roy. Soc. (London) A247,441-497 (1955)
R.W. Powers, J.B. Ziegler and H.L. Johnston, TR 264-6, Cryogenics Laboratory, Ohio State University, 17 pp (1951)

(b) G.K. White and S.B. Woods, Can. J. Physics 35, 656-665 (1957)

(c) W.R.G. Kemp, P.G. Klemens, and G.K. White, Aust. J. Physics 9, 180-188 (1956)

(d) R.W. Powers, D. Schwartz and H.L. Johnston, TR 264-5, Cryogenic Laboratory, Ohio State University 11 pp (1951)

Comments:

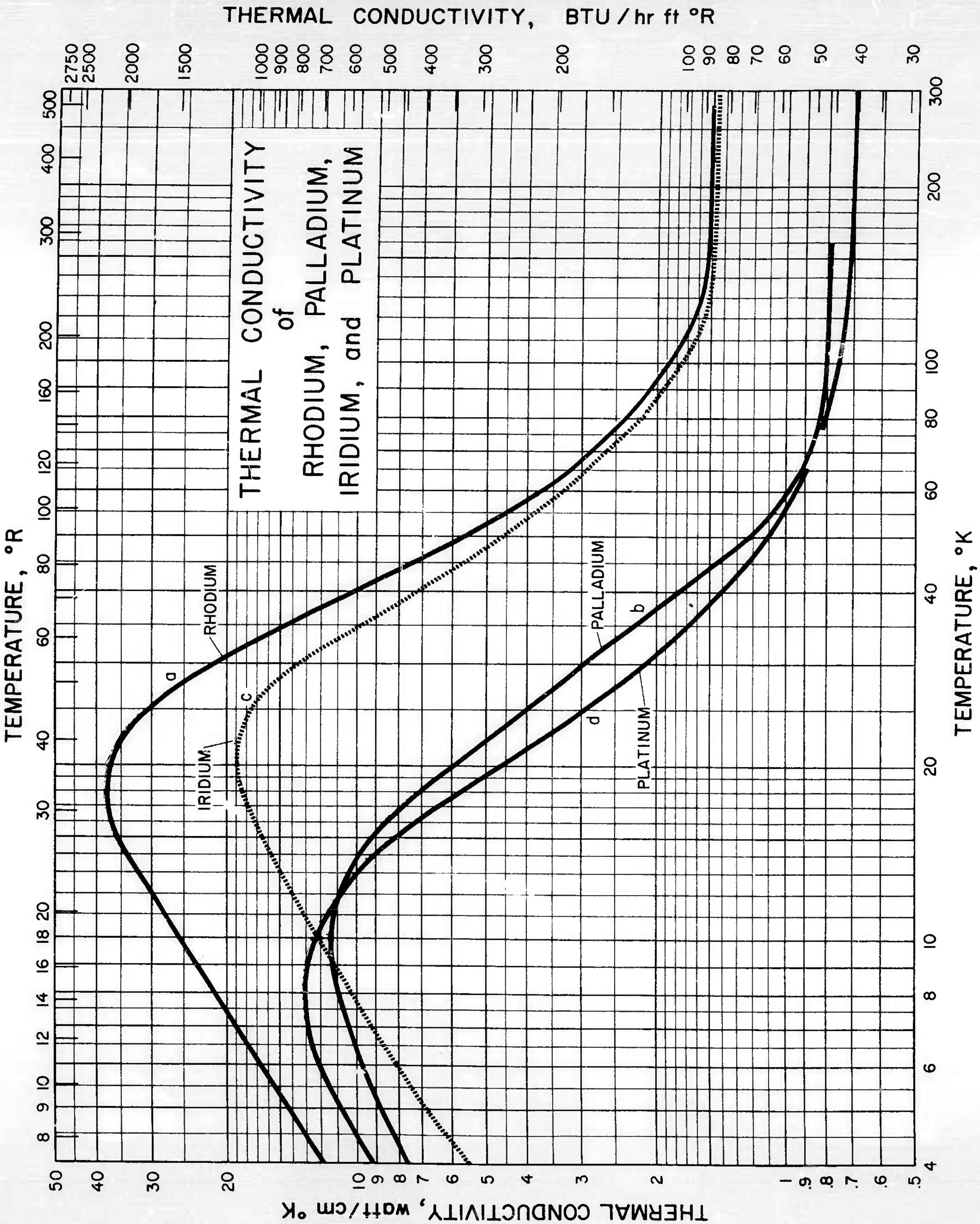
(a) Iron; 99.99% pure, annealed, (Johnson, Matthey) and 99.99% pure, (Johnson, Matthey)

(b) Cobalt; 99.99% pure, annealed, Johnson, Matthey)

(c) Nickel-1; 99.99% pure, annealed, (Johnson, Matthey)

(d) Nickel-2; 99% pure (Int. Nickel)

RLP Issued: 5/1/58
Revised: 3/1/59


THERMAL CONDUCTIVITY, BTU / hr ft °R
THERMAL CONDUCTIVITY of RHODIUM, PALLADIUM, IRIDIUM, and PLATINUM
RHODIUM
IRIDIUM
PALLADIUM
PLATINUM
a
b
c
d
TEMPERATURE, °R
TEMPERATURE, °K
THERMAL CONDUCTIVITY, watt/cm °K

THERMAL CONDUCTIVITY OF RHODIUM, PALLADIUM, IRIDIUM, AND PLATINUM

Source of Data:

(a) G.K. White and S.B. Woods, Can. J. Physics 35, 248-257 (1957); R.W. Powell and R.P. Tye, "Int. Conf. on Low Temp" Paris, Sept. 1955.

(b) W.R.G. Kemp , P.G. Klemens, A.K. Sreedhar, and G.K. White, Phil. Mag. 46, 811-814 (1955).

(c) H.M. Rosenberg, Phil. Trans. Roy. Soc. (London) A247, 441-497 (1955); R.W. Powell and R.P. Tye, "Int. Conf. on Low Temp" Paris, Sept. 1955.

(d) H.M. Rosenberg, Phil. Trans. Roy. Soc. (London) A247, 441-497 (1955); W. Meissner, Ann. Physik 47, 1001-1058 (1915.

Comments:

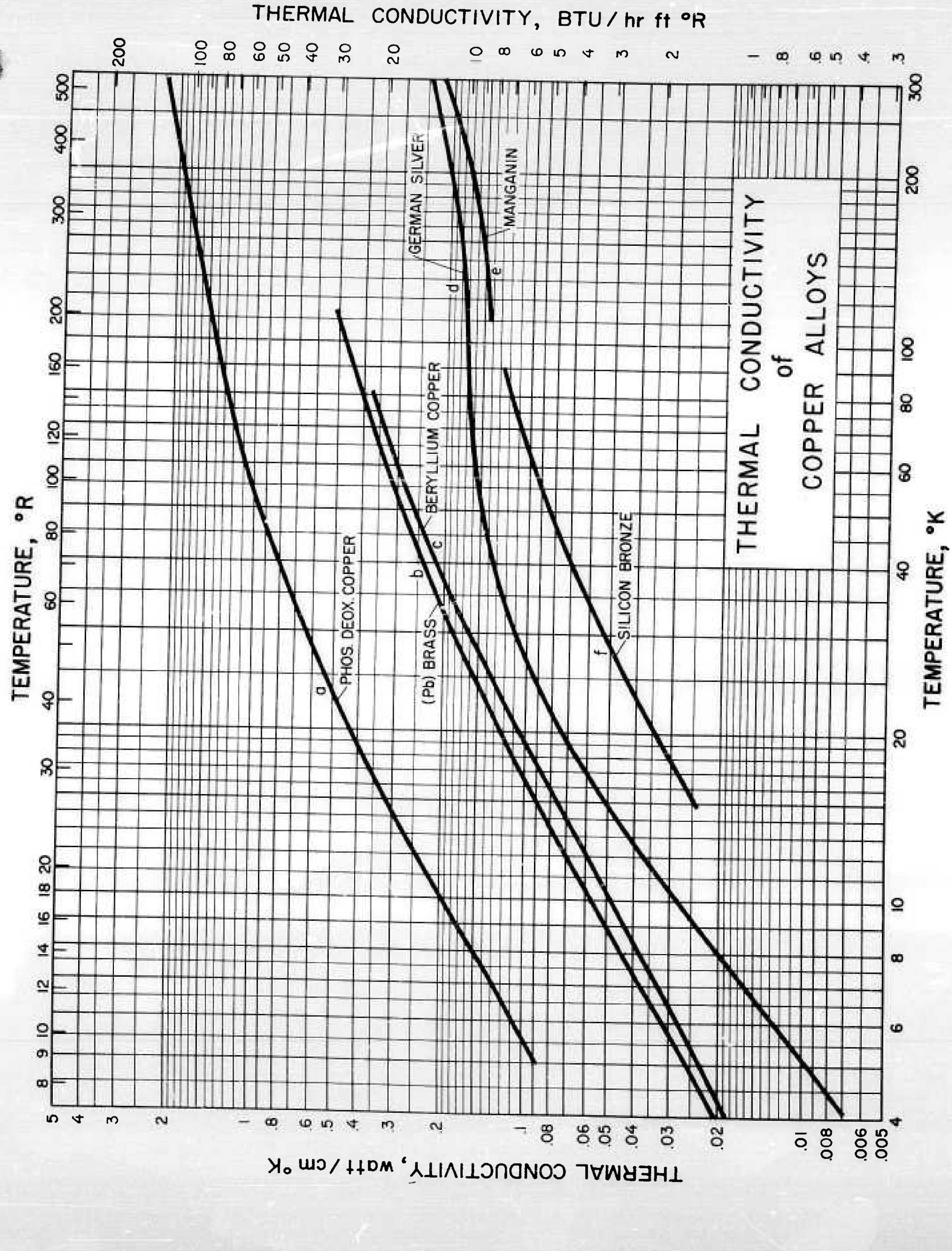
(a) Rhodium; 99.99% pure, annealed, (Johnson, Matthey) and 99.9% pure, annealed, (Johnson, Matthey)

(b) Palladium; 99.99% pure, annealed, (Johnson, Matthey)

(c) Iridium; 99.995% pure, annealed, (Johnson, Matthey) and 99.9% pure, annealed, (Johnson, Matthey)

(d) Platinum; 99.999% pure, annealed, (Johnson, Matthey), and "very pure", annealed (Heraeus).

RLP Issued: 5/1/58
Revised: 3/1/59


THERMAL CONDUCTIVITY of COPPER ALLOYS
THERMAL CONDUCTIVITY, BTU/hr ft °R
THERMAL CONDUCTIVITY, watt/cm °K
TEMPERATURE, °R
TEMPERATURE, °K
a PHOS. DEOX. COPPER
b (Pb) BRASS
c BERYLLIUM COPPER
d GERMAN SILVER
e MANGANIN
f SILICON BRONZE

THERMAL CONDUCTIVITY of COPPER ALLOYS

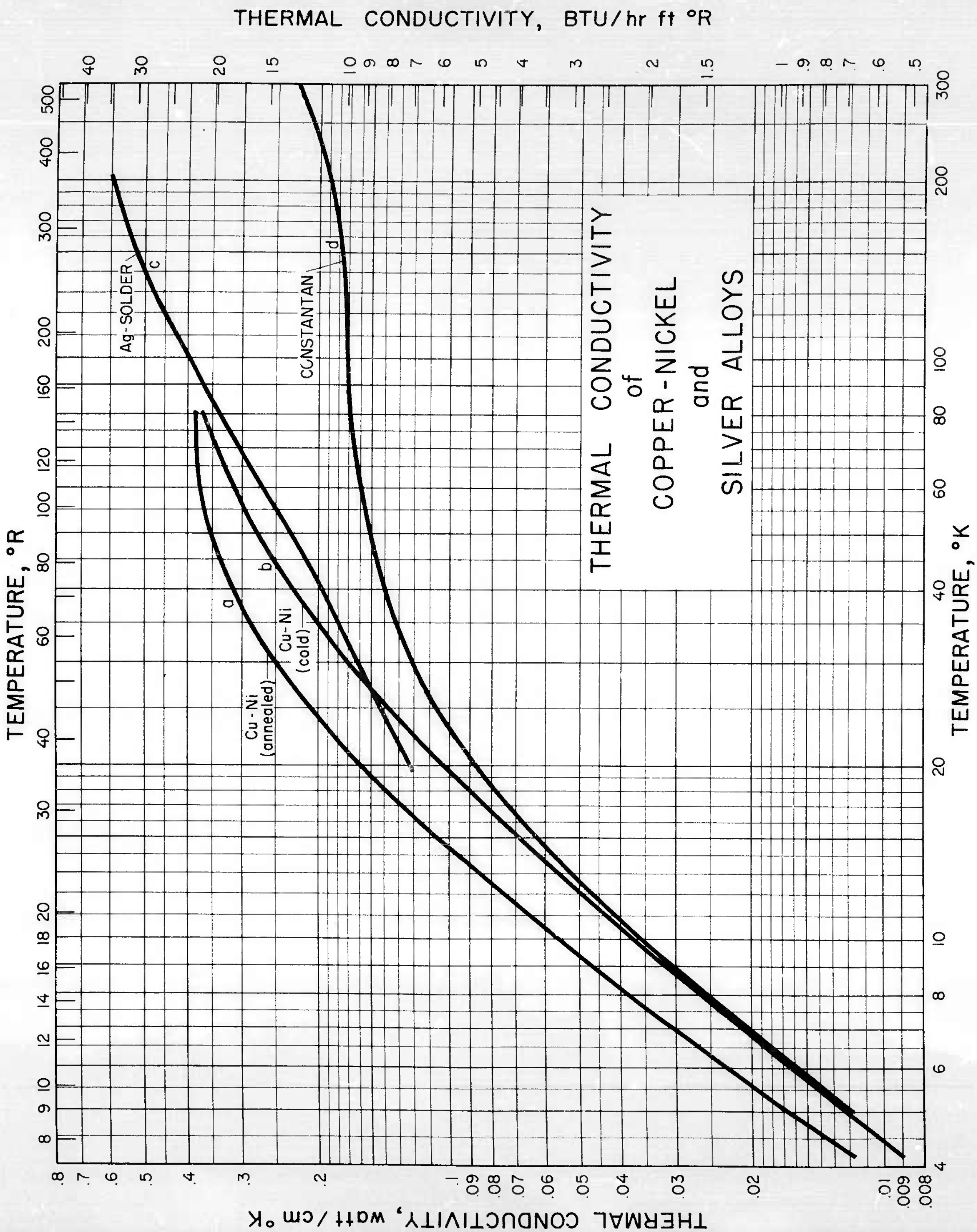
Source of Data:

(a) R. L. Powell, H. M. Roder, and W. M. Rogers, J. Appl. Phys. 28, 1282-1288 (1957).
(b) Same as (a)
(c) R. Berman, E. L. Foster, H. M. Rosenberg, Brit. J. Appl. Physics 6, 181-182 (1955).
(d) R. Berman, Phil. Mag. 42, 642-650 (1951); C. H. Lees, Phil. Trans. Roy. Soc. (London) A208, 381-443 (1908).
(e) C. H. Lees, Phil. Trans. Roy. Soc. (London) A208, 381-443 (1908).
(f) Same as (a)

Comments:

(a) Phos. Deox. Copper; 0.027% P, 99% Cu, Commercial hard temper.
(b) (Pb) Brass; 35.7% Zn, 3.27% Pb, 1% Sn, 60% Cu, hard temper.
(c) Beryllium Copper; 2% Be, 98% Cu, held at 300 °C for two hours.
(d) German Silver; 47% Cu, 41% Zn, 9% Ni, 2% Pb.; and 62% Cu, 22% Zn, 15% Ni.
(e) Manganin; 84% Cu, 12% Mn, 4% Ni.
(f) Silicon Bronze; 3.15% Si, 1.13% Mn, 1% Zn, 94% Cu, hard temper.

RLP Issued: 5/1/58
Revised: 3/1/59


THERMAL CONDUCTIVITY, BTU/hr ft °R
THERMAL CONDUCTIVITY of COPPER-NICKEL and SILVER ALLOYS
Ag-SOLDER
c
CONSTANTAN
d
Cu-Ni (cold)
b
Cu-Ni (annealed)
a
TEMPERATURE, °R
TEMPERATURE, °K
THERMAL CONDUCTIVITY, watt/cm °K

THERMAL CONDUCTIVITY of COPPER-NICKEL
and SILVER ALLOYS

Source of Data:

(a) I. Estermann and J. E. Zimmerman, J. Appl. Phys. 23, 578-588 (1952)

(b) Same as (a).

(c) R. L. Powell, Unpublished (1953)

(d) R. Berman, Phil. Mag. 42, 642-650 (1951); R. W. Powers, J. B. Zeigler and H. L Johnston, TR 264-8, Ohio State Univ. (1951)

Comments:

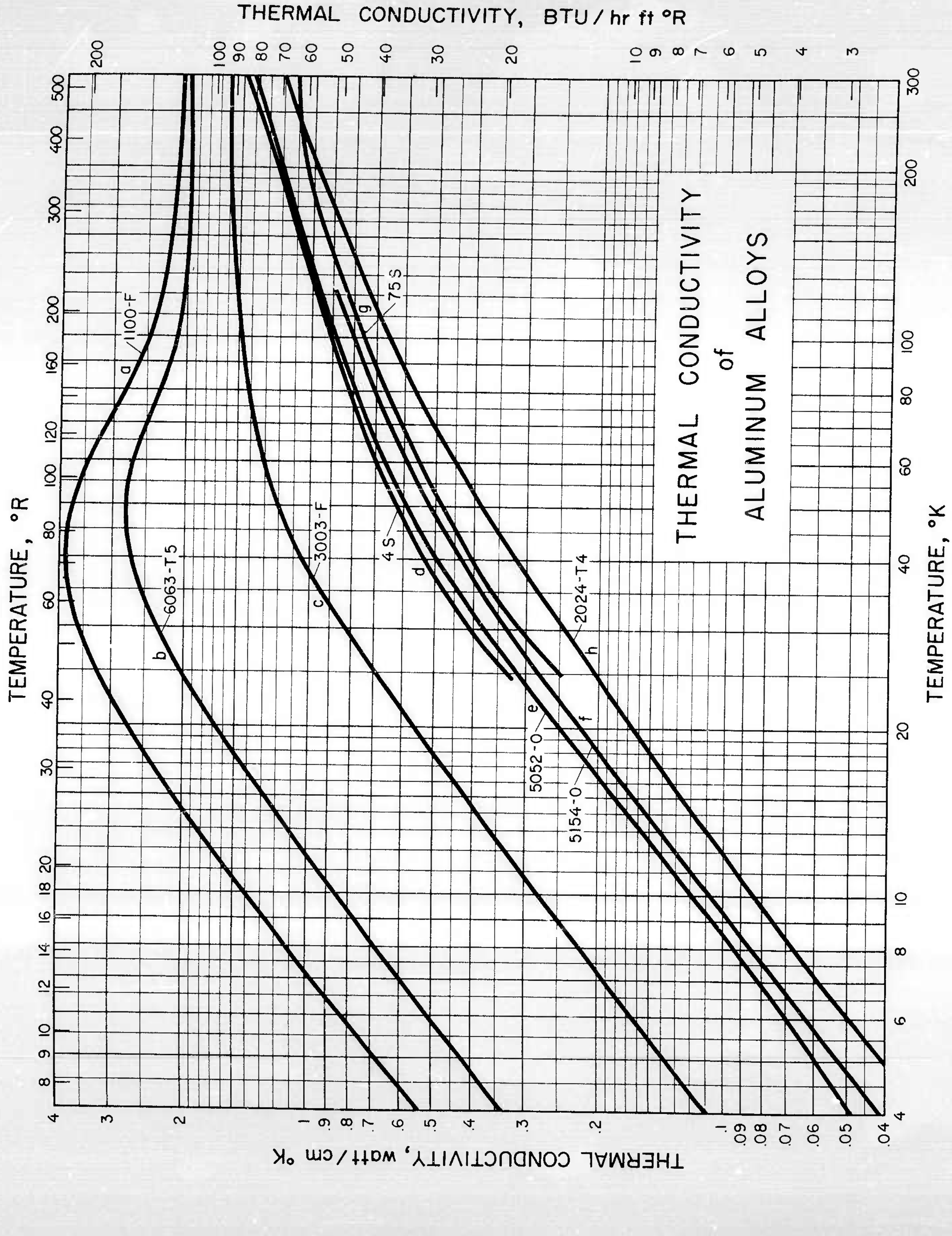
(a) Cu-Ni (annealed; 90% Cu, 10% Ni; annealed

(b) Cu-Ni (cold); 90% Cu, 10% Ni; cold-worked

(c) Ag-Solder; 50% Ag, 15.5% Cu, 16.5% Zn, 18% Cd

(d) Constantan; 60% Cu, 40% Ni; and 55% Cu, 45% Ni.

RLP Issued: 5/1/58
Revised: 3/1/59

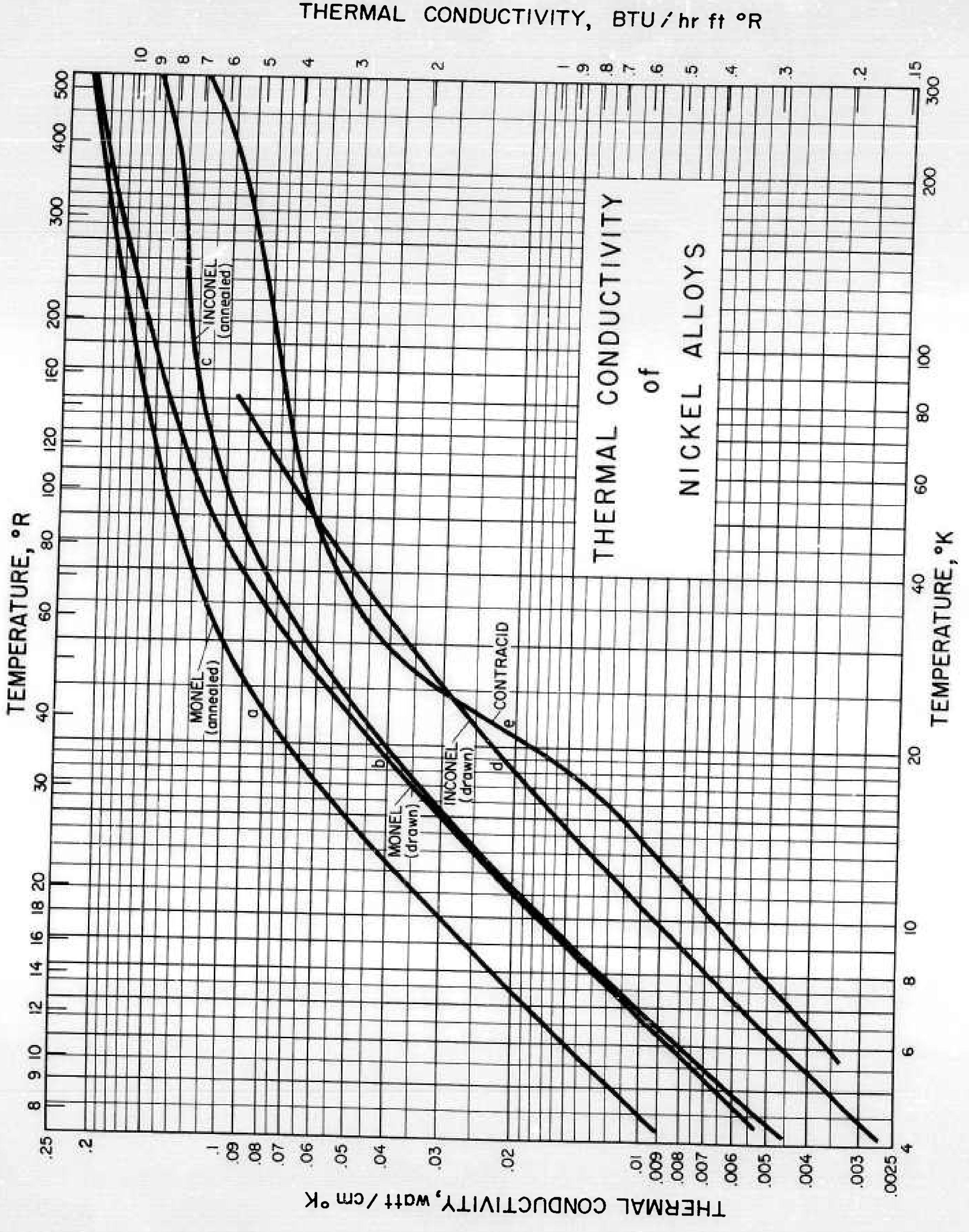

THERMAL CONDUCTIVITY, BTU / hr ft °R
THERMAL CONDUCTIVITY of ALUMINUM ALLOYS
TEMPERATURE, °R
TEMPERATURE, °K
THERMAL CONDUCTIVITY, watt/cm °K
a 1100-F
b 6063-T5
c 3003-F
d 4S
g 75S
e 5052-0
f 5154-0
h 2024-T4

THERMAL CONDUCTIVITY of ALUMINUM ALLOYS

Source of Data:
(a) R. L. Powell, W. J. Hall, and H. M. Roder, to be published (1958)
(b) Same as (a)
(c) Same as (a)
(d) R. W. Powers, J. B. Ziegler, and H. L. Johnston, TR 264-7, Cryogenics Laboratory, Ohio State University 10 pp. (1951)
(e) Same as (a)
(f) Same as (a)
(g) Same as (d)
(h) Same as (a)

Comments:
(a) 1100-F; Alcoa, 99% Al, as fabricated.
(b) 6063-T5; Alcoa, 0.4% Si, 0.7% Mg, 98.5% Al, as fabricated.
(c) 3003-F; Alcoa, 1.2% Mn, 98.5% Al, as fabricated.
(d) 4 S; 0.16% Cu, 1.02% Mg, 1.20% Mn, 0.52% Fe, 0.13% Si, 0.02% Cr, 0.02% Ti.
(e) 5052-0; 0.25% Cr, 2.5% Mg, 97% Al, annealed.
(f) 5154-0; 0.25% Cr, 3.5% Mg, 96% Al, annealed.
(g) 75-S; 1.5% Cu, 5.5% Zn, 2.5% Mg, 0.2% Mn, 0.3% Cr.
(h) 2024-T4; 0.6% Mn, 1.5% Mg, 4.5% Cu, 93% Al, solution heat treated.

RLP Issued: 5/1/58
Revised: 3/1/59


THERMAL CONDUCTIVITY, BTU / hr ft °R
THERMAL CONDUCTIVITY of NICKEL ALLOYS
TEMPERATURE, °R
TEMPERATURE, °K
THERMAL CONDUCTIVITY, watt / cm °K
MONEL (annealed)
a
MONEL (drawn)
b
INCONEL (annealed)
c
INCONEL (drawn)
d
CONTRACID
e

THERMAL CONDUCTIVITY of NICKEL ALLOYS

Source of Data:

(a) I. Estermann and J.E. Zimmerman, J. Appl. Phys. 23, 578-588 (1952); R.W. Powers, J.B. Ziegler, and H.L. Johnston, TR 264-8, Cryogenics Laboratory, Ohio State University (1951) 11 pp.

(b) Same as (a).

(c) Same as (a).

(d) I. Estermann and J.E. Zimmerman, J. Appl, Phys. 23, 578-588 (1952).

(e) J. Karweil and K. Schafer, Ann. Physik 36, 567-577 (1939); R.W. Powers, J.B. Ziegler, and H.L. Johnston, TR 264-8, Cryogenics Laboratory, Ohio State University (1951) 11 pp.

Comments:

(a) Monel; annealed; and 67%Ni, 30% Cu, 1.4% Fe, 1.0%Mn, 0.15% C, 0.1% Si, 0.01% S, hot-rolled

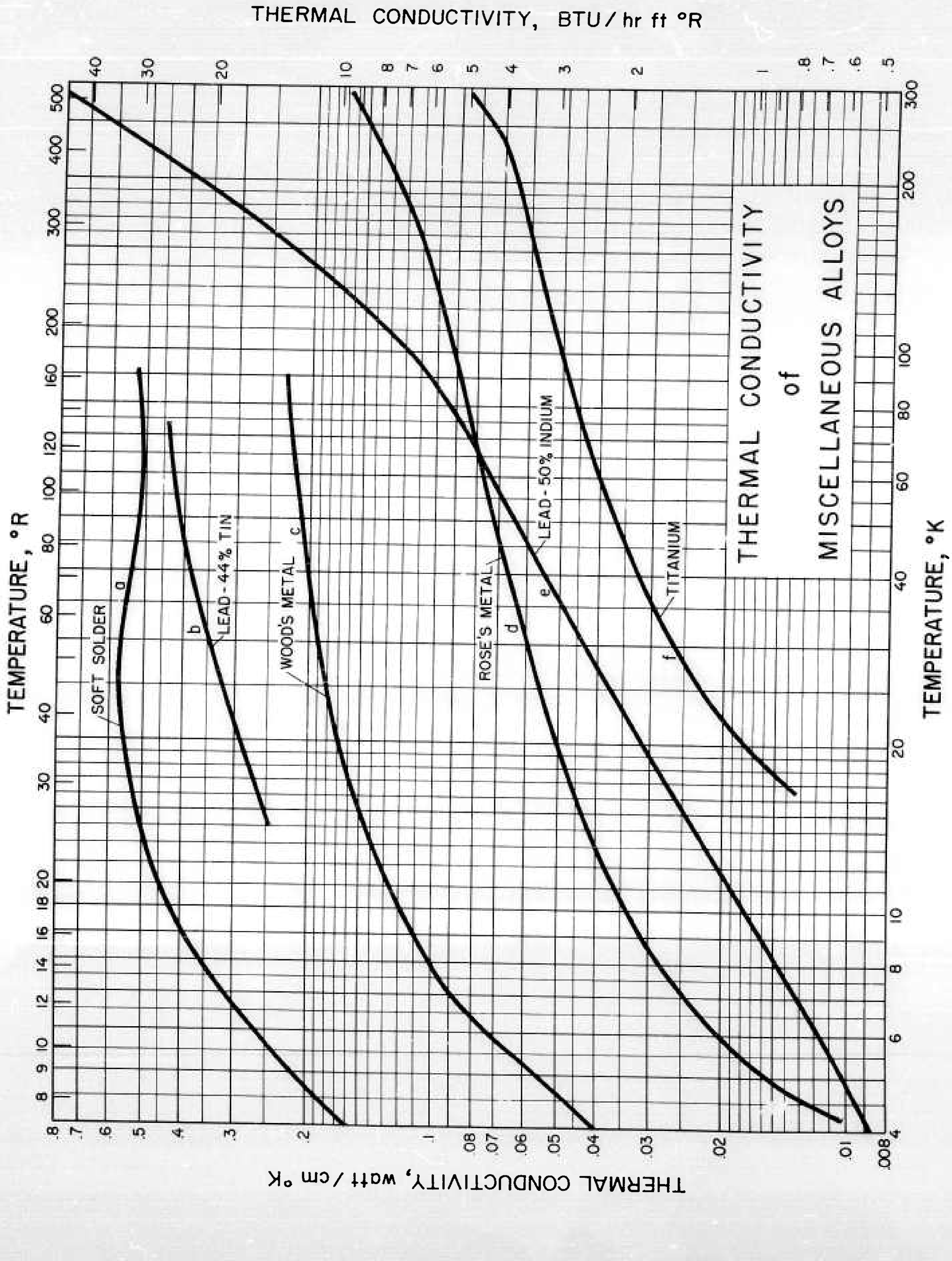
(b) Monel; Hard-drawn: and 67% Ni, 30% Cu, 1.4% Fe, 1.0% Mn, 0.15% C. 0.1% Si, 0.01% S, Cold-rolled

(c) Inconel; Annealed: and 80% Ni, 14% Cr, 6% Fe.

(d) Inconel; Hard-drawn

(e) Contracid; 60% Ni, 15% Cr, 16% Fe, 7% Mo; and 60.05% Ni, 14.74% Cr, 15.82% Fe, 7.2% Mo, 2.14% Mn, 0.05% C.

RLP Issued: 5/1/58
Revised: 3/1/59


THERMAL CONDUCTIVITY, BTU/hr ft °R
THERMAL CONDUCTIVITY of MISCELLANEOUS ALLOYS
TEMPERATURE, °R
TEMPERATURE, °K
THERMAL CONDUCTIVITY, watt/cm °K
SOFT SOLDER
a
LEAD-44% TIN
b
WOOD'S METAL
c
ROSE'S METAL
d
LEAD-50% INDIUM
e
TITANIUM
f

THERMAL CONDUCTIVITY of MISCELLANEOUS ALLOYS

Source of Data:

(a) R. Berman, E. L. Foster, and H. M. Rosenberg
Brit. J. Appl. Physics 6, 181-182 (1955)

(b) H. Bremmer and W. J. deHaas,
Physica 3, 692-704 (1936).

(c) Same as (a)

(d) Same as (b)

(e) Same as (b)

(f) W. W. Tyler and A. C. Wilson
Knolls Atomic Power Laboratory Report 803,
41 pp. (1952)

Comments:

(a) Soft Solder; 60% Sn, 40% Pb

(b) Lead - 44% Tin; 56% Pb, 44% Sn

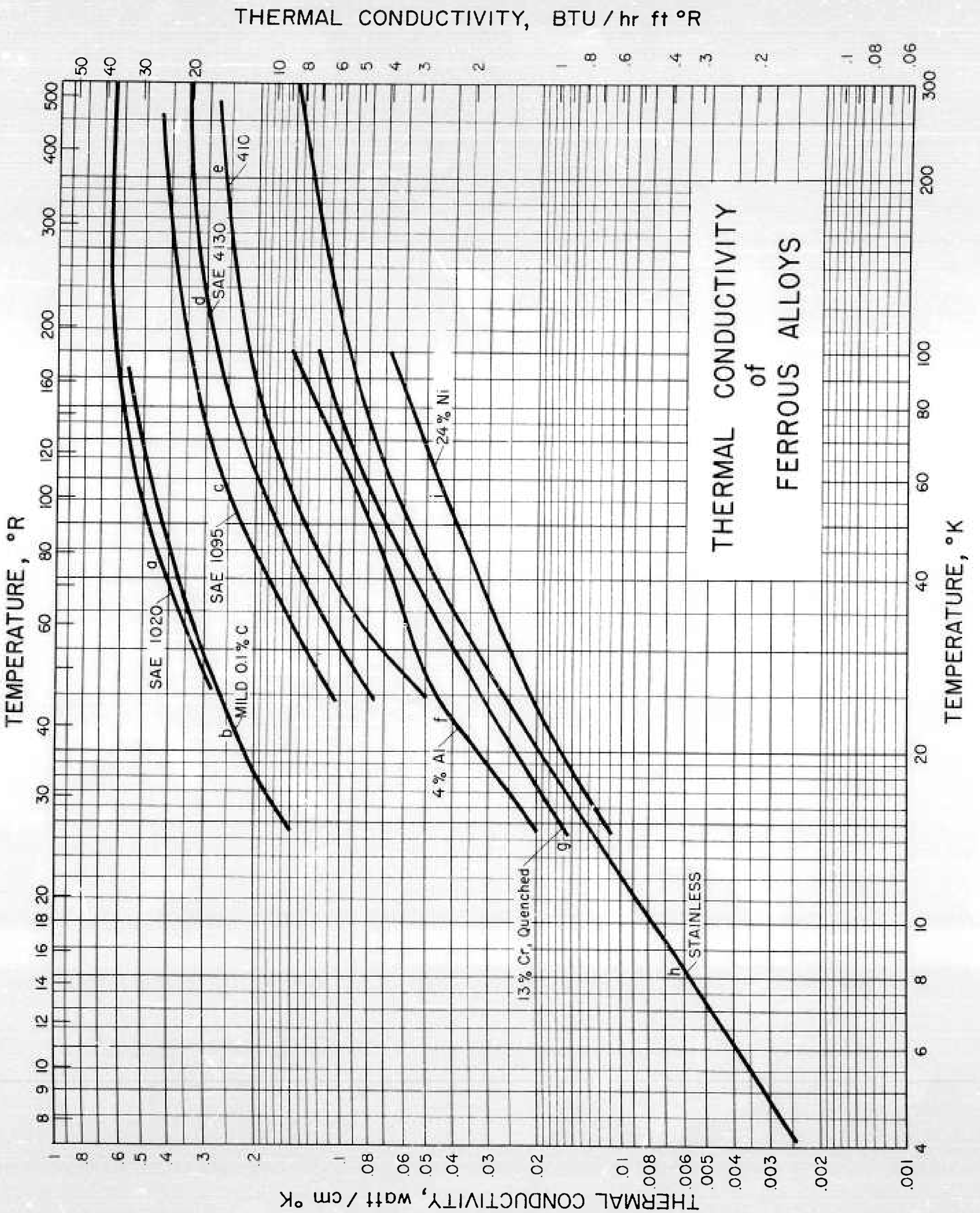
(c) Wood's Metal; 48% Pb, 13% Sn, 13% Cd

(d) Rose's Metal; 50% Bi, 25% Pb, 25% Sn

(e) Lead - 50% Indium; 50% In, 50% Pb

(f) Titanium; Rem - Cru, RC130-B, 4.7% Mn, 3.99% Al, 0.14% C.

RLP Issued: 5/1/58
Revised: 3/1/59

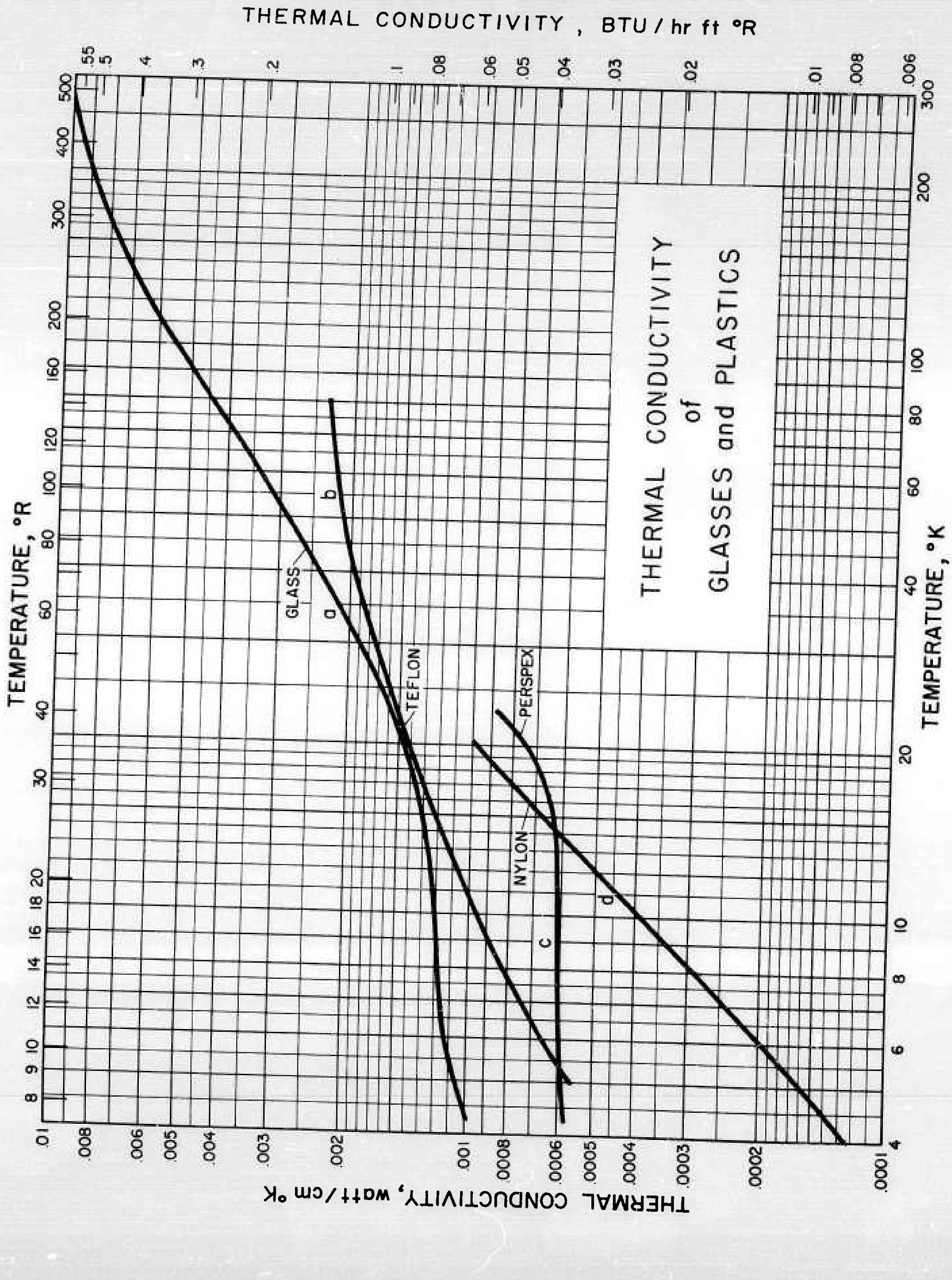

THERMAL CONDUCTIVITY, BTU / hr ft °R
THERMAL CONDUCTIVITY of FERROUS ALLOYS
TEMPERATURE, °R
TEMPERATURE, °K
THERMAL CONDUCTIVITY, watt / cm °K
SAE 1020
MILD 0.1 % C
SAE 1095
SAE 4130
410
4 % Al
13 % Cr, Quenched
STAINLESS
24 % Ni
a
b
c
d
e
f
g
h
i

THERMAL CONDUCTIVITY of FERROUS ALLOYS

Source of Data:
(a) R. W. Powers, J. B. Ziegler, and H. L. Johnston, TR 264-6, Cryogenic Laboratory, Ohio State University 17, (1951)
(b) J. deNobel, Physica 17, 551-562 (1951)
(c) Same as (a)
(d) Same as (a)
(e) Same as (a)
(f) Same as (b)
(g) Same as (b)
(h) R. L. Powell, and W. A. Blanpied, NBS Circular 556, 68 pp. (1954)
(i) Same as (b)

Comments:
(a) SAE 1020; 0.33% Mn, 0.18%C, 0.014% Si.
(b) Mild 0.1% C; 0.14% C, 0.08% Si, 0.07% Mn; heated to 800°C and furnace cooled.
(c) SAE 1095; 0.93% C, 0.34% Mn, 0.26% Si, 0.1% Ni, Cr, 0.05% Mo.
(d) SAE 4130; 0.99% Cr, 0.52% Mn, 0.33% C, 0.2% Si, Ni, and Mo.
(e) 410; 12.6% Cr, 0.36% Si, 0.32% Mn, 0.12% Ni, 0.09% C, 0.06% Cu, 0.03% N, 0.01% P.
(f) 4% Al; 4.11% Al, 0.13% Si, 0.08% Mn, 0.03% C, 0.01% Si, heated to 800°C and furnace cooled.
(g) 13% Cr; 13.5% Cr, 0.36% C, 0.22% Si, 0.13% Mn, heated to 950°C, oil quenched, reheated to 450°C, air-cooled.
(h) Stainless; average value for close curves of types 303, 304, 316, 347, and "stainless" as compiled in NBS Circular 556.
(i) 24% Ni; 24.30% Ni, 6.05% Mn, 1.18% C, heated to 1050°C and water-quenched.

RLP Issued: 5/1/58
Revised: 3/1/59


THERMAL CONDUCTIVITY , BTU / hr ft °R
THERMAL CONDUCTIVITY of GLASSES and PLASTICS
TEMPERATURE, °R
TEMPERATURE, °K
THERMAL CONDUCTIVITY, watt / cm °K
GLASS
TEFLON
PERSPEX
NYLON
a
b
c
d
.55
.5
.4
.3
.2
.1
.08
.06
.05
.04
.03
.02
.01
.008
.006
500
400
300
200
160
120
100
80
60
40
30
20
18
16
14
12
10
9
8
300
200
100
80
60
40
20
10
8
6
4
.01
.008
.006
.005
.004
.003
.002
.001
.0008
.0006
.0005
.0004
.0003
.0002
.0001

THERMAL CONDUCTIVITY OF GLASSES and PLASTICS

Source of Data:

(a) R. L. Powell and W. A. Blanpied, NBS Circular 556, 68 (1954)

(b) R. L. Powell, W. M. Rogers, and D. O. Coffin J. Research NBS, 59, 349-355 (1957)

(c) R. Berman, E. L. Foster and H. M. Rosenberg Brit. J. Appl. Physics 6, 181-182 (1955)

(d) R. Berman Proc. Roy. Soc. (London) A208, 90-108 (1951)

Comments:

(a) Glass; average value of quartz, Pyrex, and borosilicate glasses.

(b) Teflon; extruded

(c) Nylon; Imperial Chem. Ind.; drawn monofilament.

(d) Perspex; An English organic glass thermo-plastic similar to Lucite or Plexiglass.

RLP Issued: 5/1/58
Revised: 3/1/59

SPECIFIC HEAT and ENTHALPY of CRYOGENIC SOLIDS

CONTENTS

(continued)

SPECIFIC HEAT and ENTHALPY of CRYOGENIC SOLIDS (cont.)

CONTENTS

SPECIFIC HEAT, ENTHALPY of SODIUM

Sources of Data:

Eastman, E. D. and Rodebush, W. H., J. Am. Chem. Soc. 40, 489 (1918)

Roberts, L. M., Proc. Phys. Soc. (London) B70, 744 (1957)

Simon, F. and Zeidler, W., Z. physik. Chem. 123, 383 (1926)

Other References:

Dauphinee, T. M., Mac Donald, D. K. C. and Preston-Thomas, H., Proc. Roy. Soc. (London) A221, 267-276 (1954)

Griffiths, E. G. and Griffiths, E., Phil. Trans. Roy. Soc. London A214, 319 (1914); Proc. Roy. Soc. (London) A90, 557 (1914)

Gunther, P., Ann. phys. (4) 63, 476 (1920)

Koref, F., Ann. phys. (4) 36, 49 (1911)

Martin, D. L., Phys. Rev. Letters 1, 4-5 (1958)

Parkinson, D. H. and Quarrington, J. E., Proc. Phys. Soc. (London) A68, 762 (1955)

Pickard, G. L. and Simon, F., Proc. Phys. Soc. (London) 61, 1 (1948)

Rayne, J. A., Phys. Rev. 95, 1428 (1954)

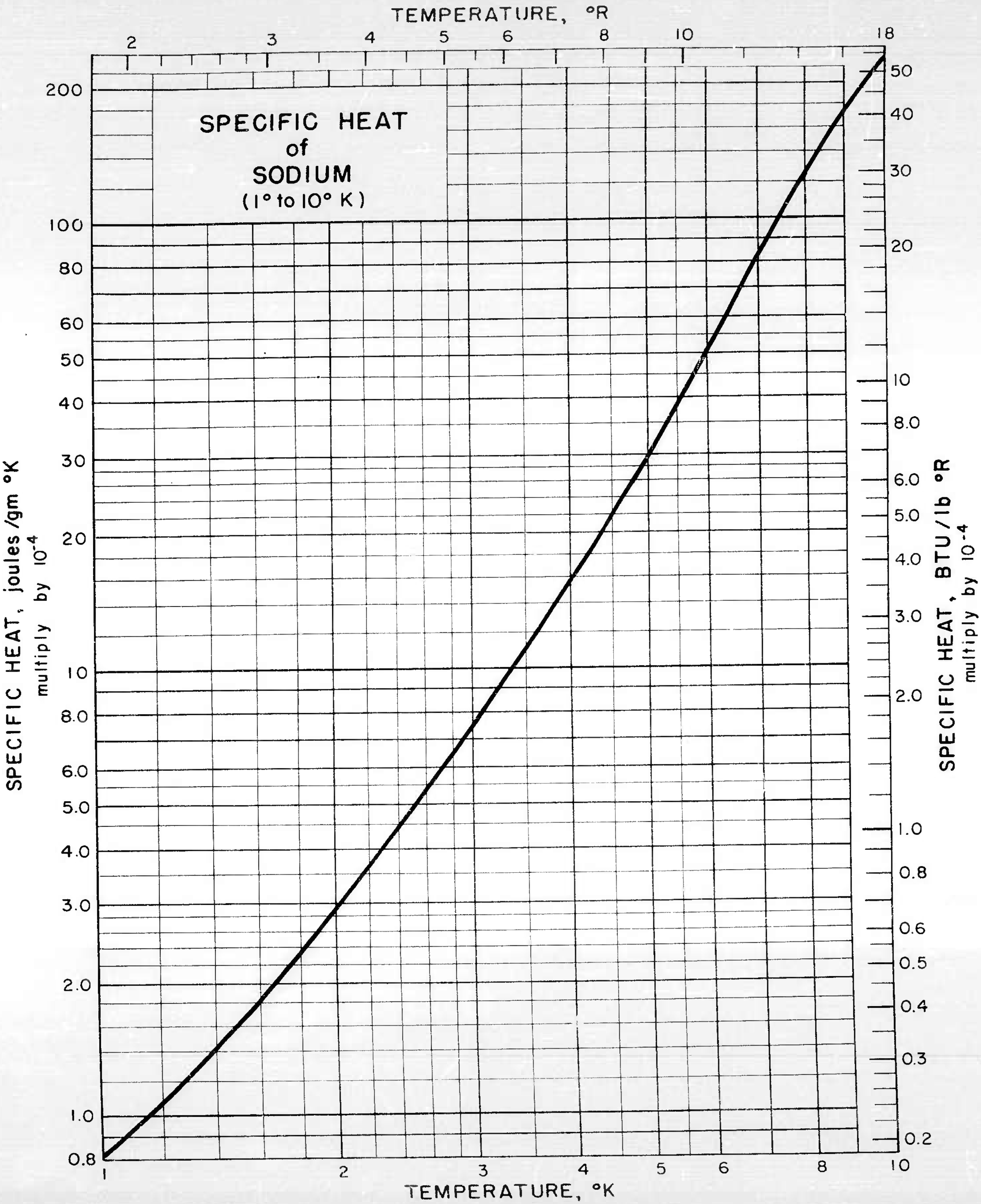
Comments:

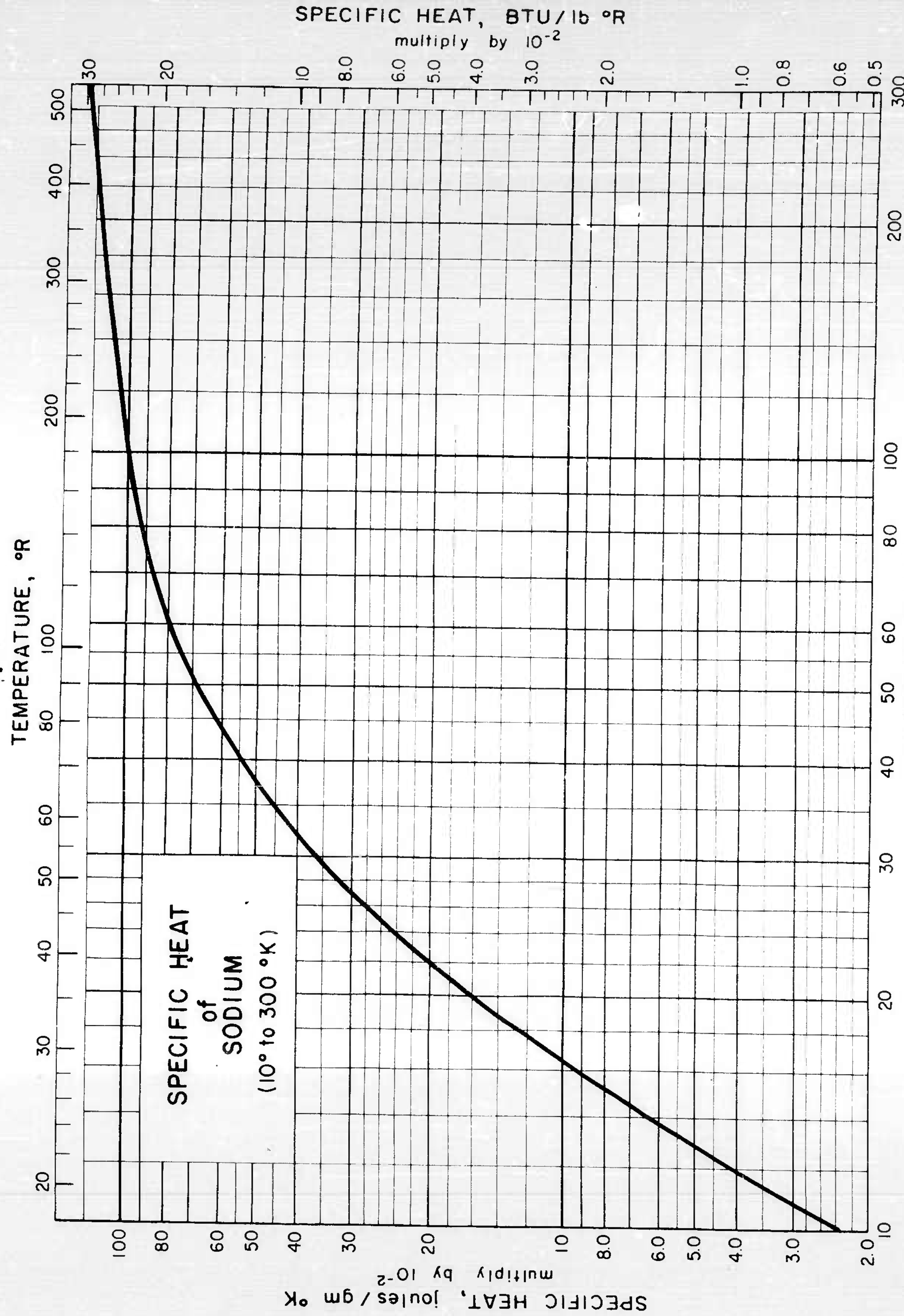
Barrett, C. S. (Acta Cryst 9, 671-7 [1956]), has shown that sodium on cooling below 36°K may transform to the extent of a few percent from the normal body centered cubic structure to a close-packed hexagonal structure. The transformation is of the martensite type and is prompted by cold work at low temperatures. The cph structure persisted to about 100°K on warming. Inasmuch as none of the calorimetric measurements on sodium were accompanied by crystallographic analysis, the tabulated data are to some degree ambiguous below 100°K.

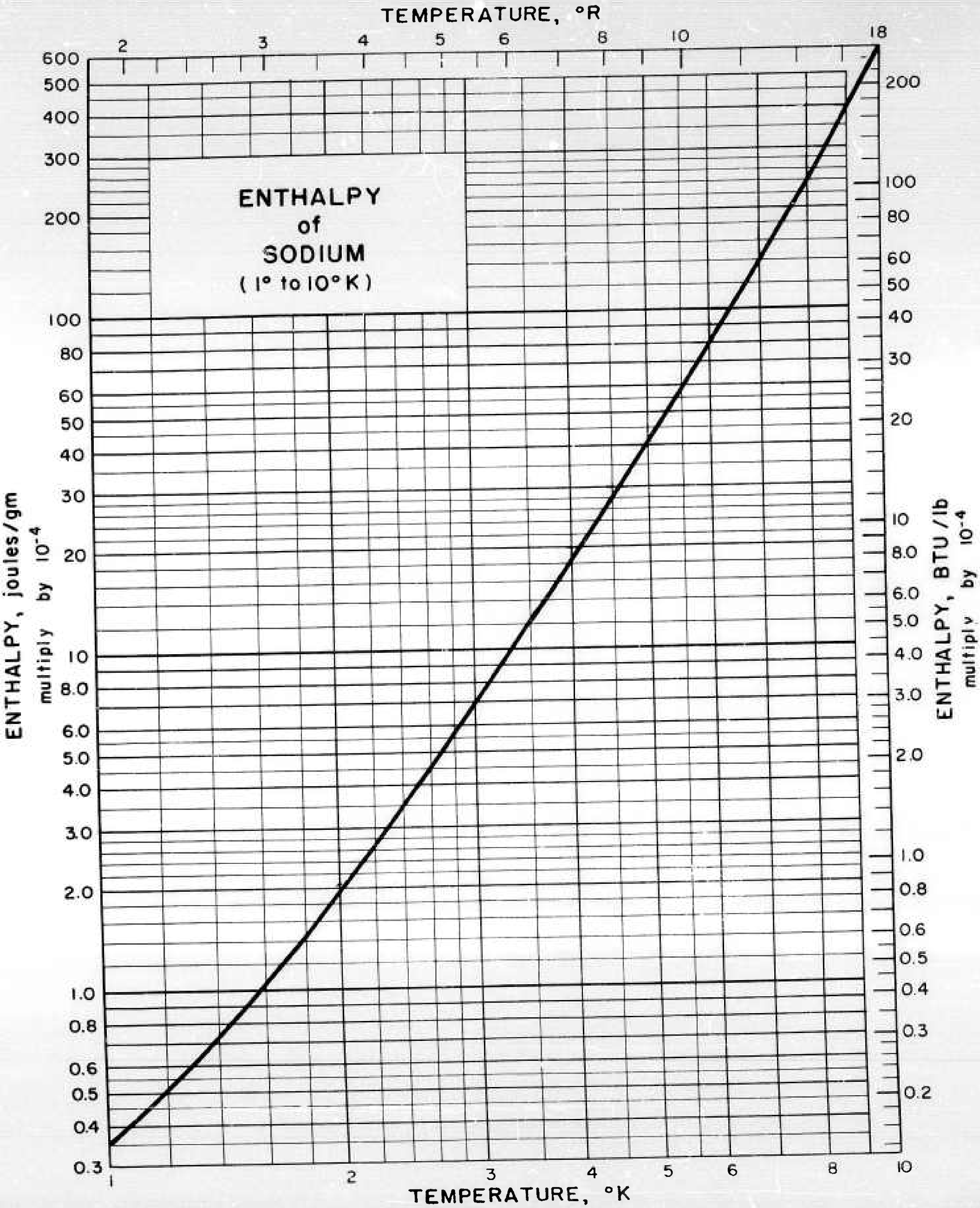
Table of Selected Values

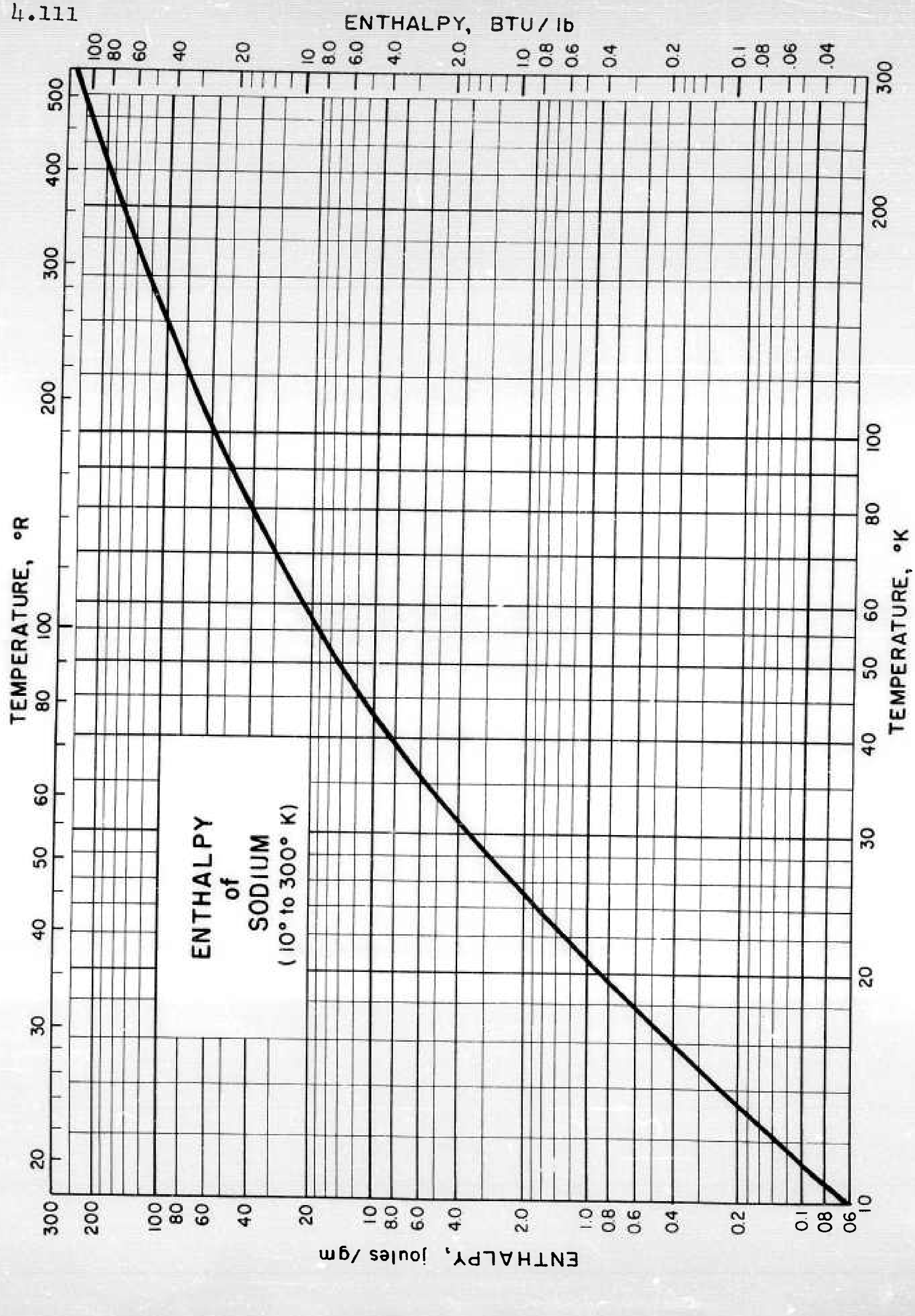
Temp. °K	C_p j/gm-°K	H j/gm	Temp. °K	C_p j/gm-°K	H j/gm	Temp. °K	C_p j/gm-°K	H j/gm
1	0.000 081	0.000 035	18	0.124	0.597	120	1.03	78.0
2	.000 289	.000 204	20	.155	0.875	140	1.06	98.9
3	.000 76	.000 70	25	.259	1.90	160	1.09	120.5
4	.001 60	.001 84	30	.364	3.45	180	1.12	142.6
5	.002 98	.004 08	40	.544	8.03	200	1.14	165.2
6	.005 1	.008 1	50	.695	14.2	220	1.16	188.2
8	.012 2	.024 7	60	.793	21.7	240	1.18	211.6
10	.023 8	.060 2	70	.86	30.0	260	1.20	235.4
12	.039 7	.123	80	.91	38.9	280	1.22	259.6
14	.063	.225	90	.95	48.2	300	1.24	284.2
16	.093	.380	100	.98	57.9			

RJC Issued: 6-5-59
Revised: 5-20-60


TEMPERATURE, °R
2
3
4
5
6
8
10
18
SPECIFIC HEAT
of
SODIUM
(1° to 10° K)
200
100
80
60
50
40
30
20
10
8.0
6.0
5.0
4.0
3.0
2.0
1.0
0.8
SPECIFIC HEAT, joules /gm °K
multiply by 10^{-4}
50
40
30
20
10
8.0
6.0
5.0
4.0
3.0
2.0
1.0
0.8
0.6
0.5
0.4
0.3
0.2
SPECIFIC HEAT, BTU/lb °R
multiply by 10^{-4}
1
2
3
4
5
6
8
10
TEMPERATURE, °K


SPECIFIC HEAT, BTU/lb °R
multiply by 10^{-2}
TEMPERATURE, °R
TEMPERATURE, °K
SPECIFIC HEAT
of
SODIUM
(10° to 300 °K)
SPECIFIC HEAT, joules/gm °K
multiply by 10^{-2}


TEMPERATURE, °R
2
3
4
5
6
8
10
18
ENTHALPY
of
SODIUM
(1° to 10° K)
ENTHALPY, joules/gm
multiply by 10^{-4}
600
500
400
300
200
100
80
60
50
40
30
20
10
8.0
6.0
5.0
4.0
3.0
2.0
1.0
0.8
0.6
0.5
0.4
0.3
ENTHALPY, BTU/lb
multiply by 10^{-4}
200
100
80
60
50
40
30
20
10
8.0
6.0
5.0
4.0
3.0
2.0
1.0
0.8
0.6
0.5
0.4
0.3
0.2
1
2
3
4
5
6
8
10
TEMPERATURE, °K


ENTHALPY, BTU/lb
TEMPERATURE, °R
TEMPERATURE, °K
ENTHALPY, joules/gm
ENTHALPY
of
SODIUM
(10° to 300° K)

SPECIFIC HEAT, ENTHALPY of COPPER

(1° to 10°K)

Sources of Data:

Corak, W. S., Garfunkel, M. P., Satterthwaite, C. B. and Wexler, A., Phys. Rev. 98, 1699-1707 (1955)

Rayne, J. A., Australian J. Phys. 9, 189-97 (1956)

Other References:

Estermann, I., Friedberg, S. A., and Goldman, J. E., Phys. Rev. 87, 582 (1952)

Kok, J. A. and Keesom, W. H., Physica 3, 1035-45 (1936)

Phillips, N. E., Low Temperature Physics and Chemistry, Univ. Wisconsin Press (1958) pp. 414-7

Comments:

For the temperature range 0° to 10°K, the specific heat follows the equation:

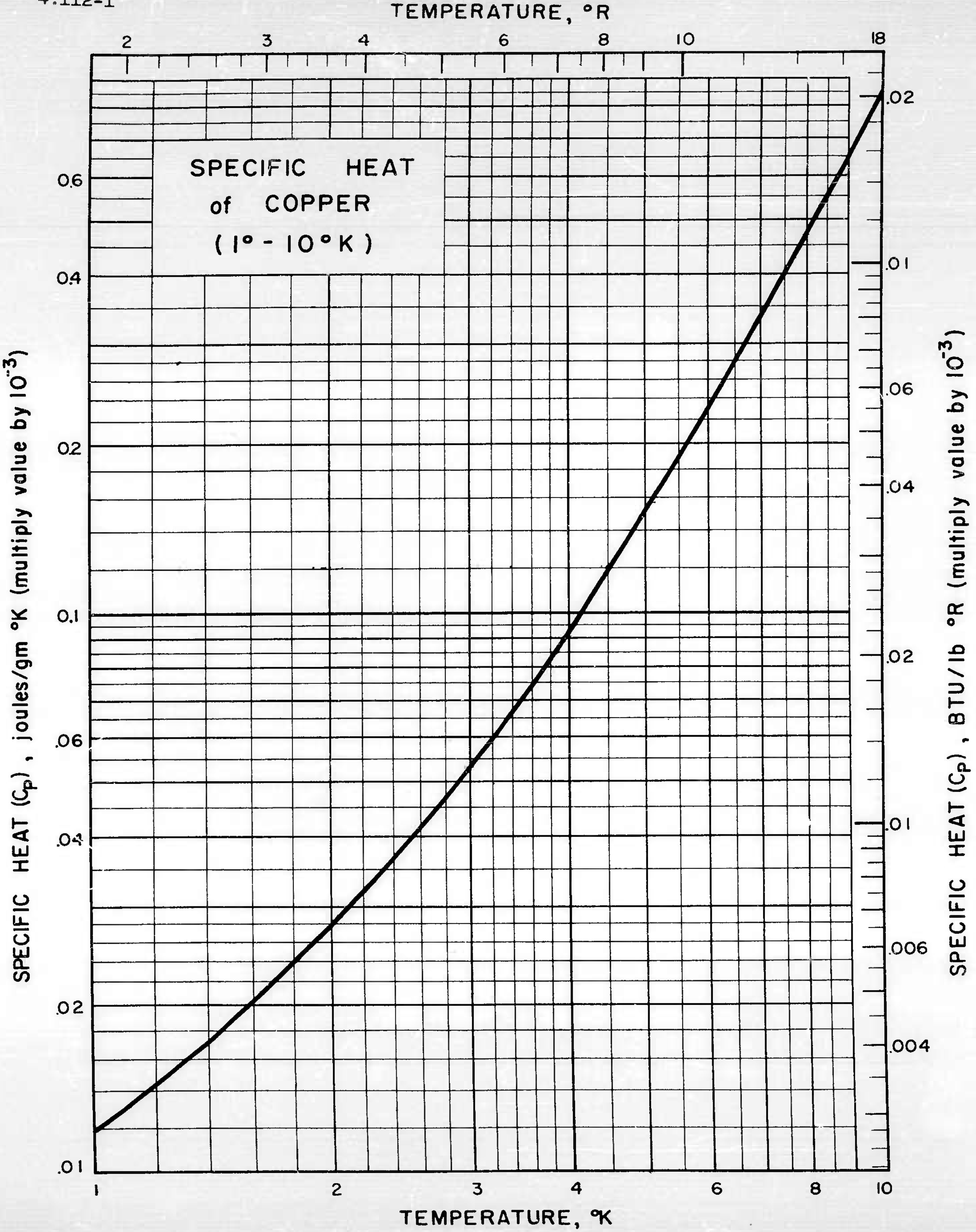
$$C_p = 10.8 \times 10^{-6}\,T + 30.6 \left[\frac{T}{344.5}\right]^3 \text{ j/gm-°K}$$

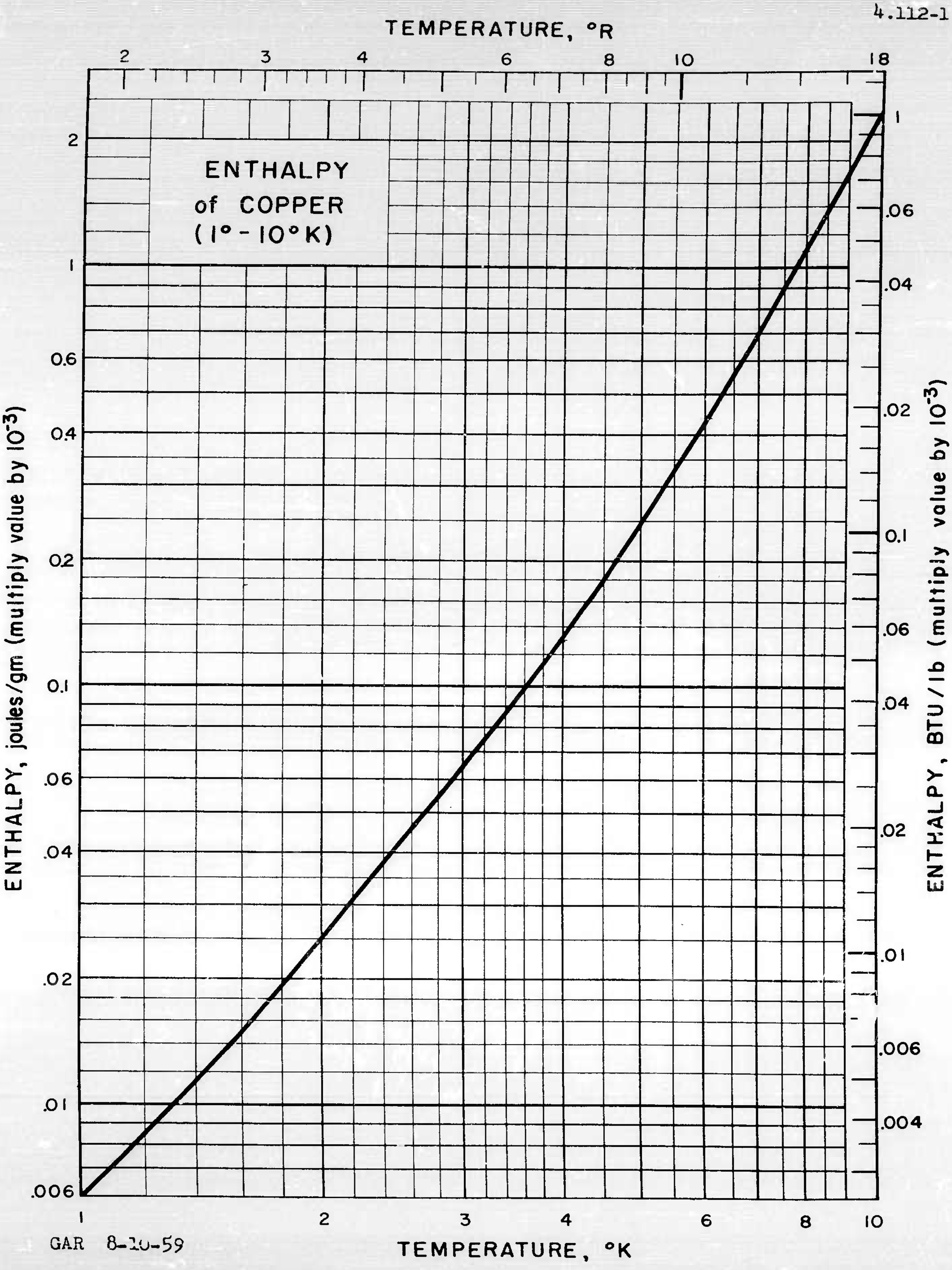
Table of Selected Values

Temp. °K	C_p j/gm-°K	H * j/gm
1	0.000 012	0.000 006
2	.000 028	.000 025
3	.000 053	.000 064
4	.000 091	.000 13
6	.000 23	.000 44
8	.000 47	.001 12
10	.000 86	.002 4

$$* \; H = \int_0^T C_p \, dT$$

RJC/VDA Issued: 10-13-59


TEMPERATURE, °R
2
3
4
6
8
10
18
SPECIFIC HEAT
of COPPER
(1° - 10°K)
0.6
0.4
0.2
0.1
.06
.04
.02
.01
.02
.01
.06
.04
.02
.01
.006
.004
SPECIFIC HEAT (C_p), joules/gm °K (multiply value by 10^{-3})
SPECIFIC HEAT (C_p), BTU/lb °R (multiply value by 10^{-3})
1
2
3
4
6
8
10
TEMPERATURE, °K


TEMPERATURE, °R
2
3
4
6
8
10
18
ENTHALPY
of COPPER
(1° - 10° K)
ENTHALPY, joules/gm (multiply value by 10^{-3})
2
1
0.6
0.4
0.2
0.1
.06
.04
.02
.01
.006
ENTHALPY, BTU/lb (multiply value by 10^{-3})
1
.06
.04
.02
0.1
.06
.04
.02
.01
.006
.004
1
2
3
4
6
8
10
TEMPERATURE, °K
GAR 8-10-59

SPECIFIC HEAT, ENTHALPY of COPPER
(10° to 300°K)

Sources of Data:

Dockerty, S. M., Can. J. Research 15A, 59-66 (1937)

Other References:

Aoyama, S. and Kanda, E., J. Chem. Soc. Japan 62, 312-15 (1941)

Behn, U., Ann. Physik u. Chem. (3) 66, 237-44 (1898)

Bronson, H. L., Chisholm, H. M. and Dockerty, S. M., Can. J. Research 8, 282-303 (1933)

Eucken, A. and Werth, H., Z. anorg. allgem. Chem. 188, Schenck Festschrift, 152-72 (1930)

Giauque, W. F. and Meads, P. F., J. Am. Chem. Soc. 63, 1897-1901 (1941)

Keesom, W. H. and Onnes, H. K., Communs. Phys. Lab. Univ. Leiden No. 147a, 3 (1915)

Koref, F., Ann. Physik 36, 49-73 (1911)

Nernst, W., Sitzber. kgl. preuss. Akad. Wiss. 262 (1910)

Nernst, W., Sitzber, kgl. preuss. Akad. Wiss. 306 (1911)

Nernst, W. and Lindemann, F. A., Z. Elektrochem. 17, 817 (1911)

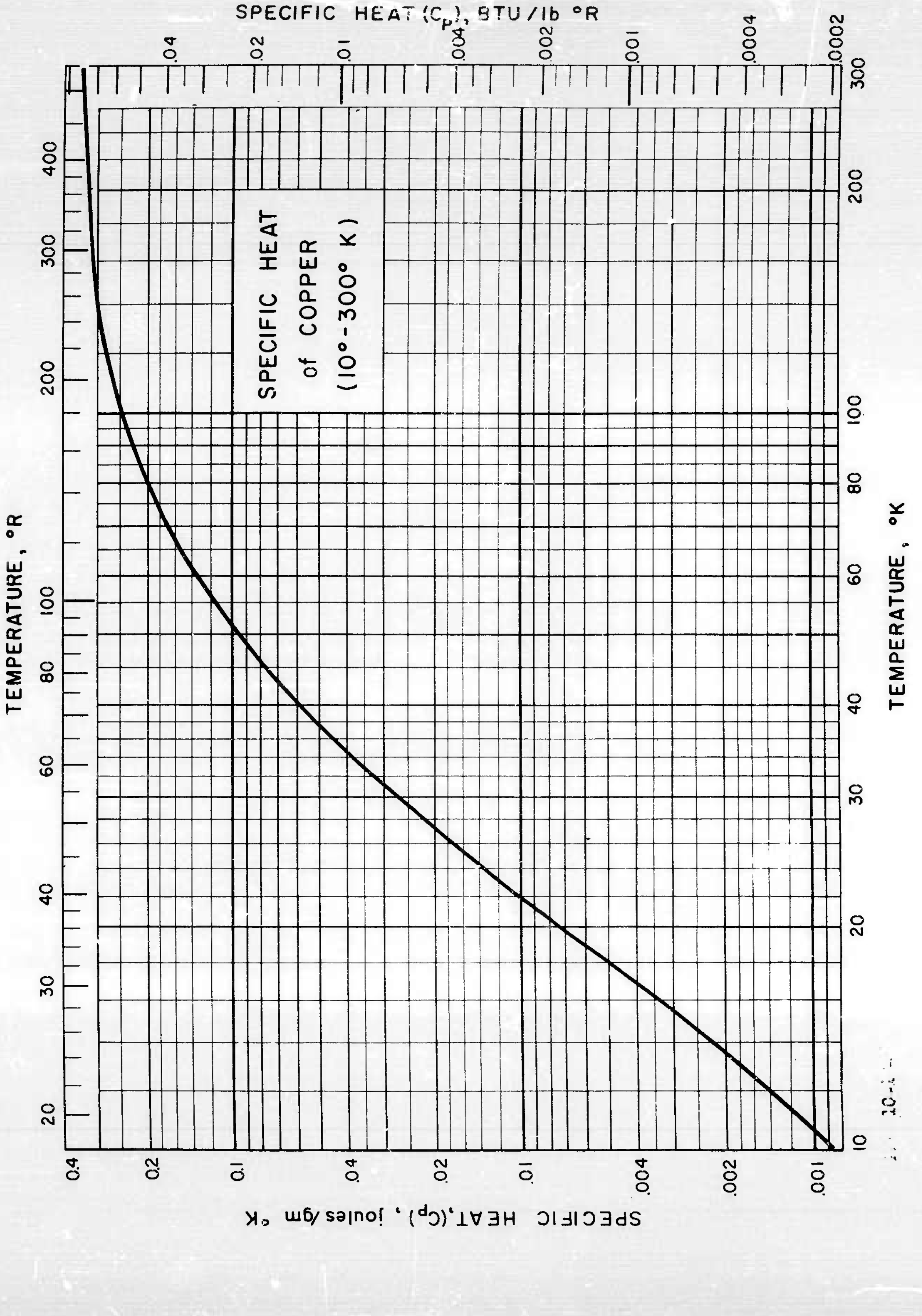
Schimpff, H., Z. physik. Chem. 71, 257 (1910)

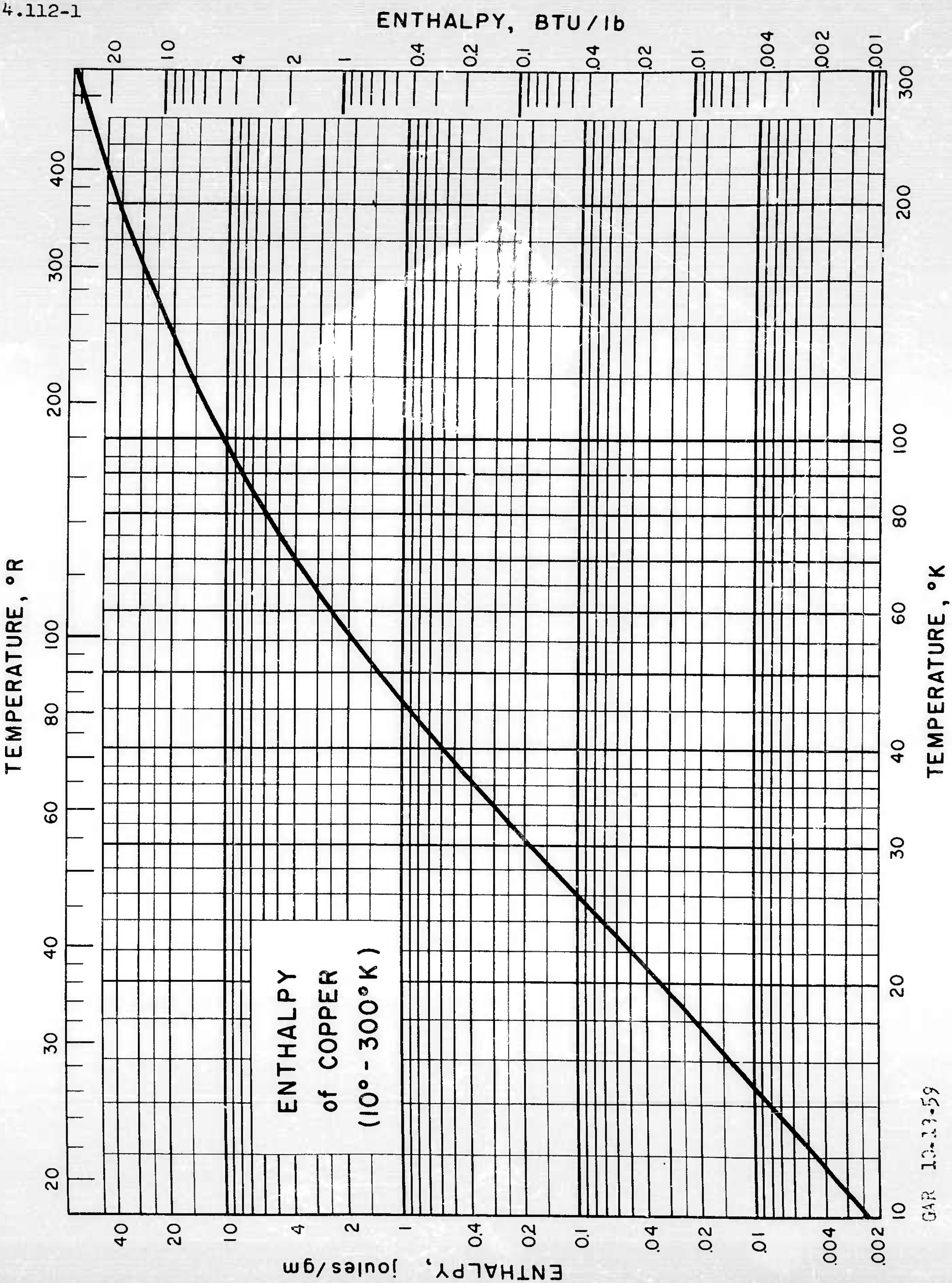
Table of Selected Values

Temp. °K	C_p j/gm-°K	H* j/gm	Temp. °K	C_p j/gm-°K	H* j/gm
10	0.000 86	0.0024	100	0.254	10.6
15	.002 7	.0107	120	.288	16.1
20	.007 7	.034	140	.313	22.1
25	.016	.090	160	.332	28.5
30	.027	.195	180	.346	35.3
40	.060	.61	200	.356	42.4
50	.099	1.40	220	.364	49.6
60	.137	2.58	240	.371	56.9
70	.173	4.13	260	.376	64.4
80	.205	6.02	280	.381	72.0
90	.232	8.22	300	.386	79.6

$$* \; H = \int_0^T C_p dT$$

RJC/VDA Issued: 12-16-59


SPECIFIC HEAT (Cp), BTU/lb °R
SPECIFIC HEAT of COPPER (10°-300° K)
TEMPERATURE, °R
TEMPERATURE, °K
SPECIFIC HEAT, (Cp), joules/gm °K
.4
.2
.1
.04
.02
.01
.004
.002
.001
.0004
.0002
0.4
0.2
0.1
20
30
40
60
80
100
200
300
400
10


ENTHALPY
of COPPER
(10° - 300°K)
ENTHALPY, BTU/lb
20 10 4 2 1 0.4 0.2 0.1 .04 .02 .01 .004 .002 .001
ENTHALPY, joules/gm
40 20 10 4 2 1 0.4 0.2 0.1 0.4 .02 .01 .004 .002
TEMPERATURE, °R
20 30 40 60 80 100 200 300 400
TEMPERATURE, °K
10 20 30 40 60 80 100 200 300
GAR

SPECIFIC HEAT, ENTHALPY of GOLD

Sources of Data:

Corak, W. S., Garfunkel, M. P., Satterthwaite, C. B. and Wexler, A., Phys. Rev. 98, 1699 (1955)

Geballe, T. H. and Giauque, W. F., J. Am. Chem. Soc. 74, 2368-9 (1952)

Other References:

Clusius, K. and Harteck, P., Z. physik. Chem. 134, 243 (1928)

Richards, T. W. and Jackson, F. G., Z. physik. Chem. 70, 414 (1910)

Comments:

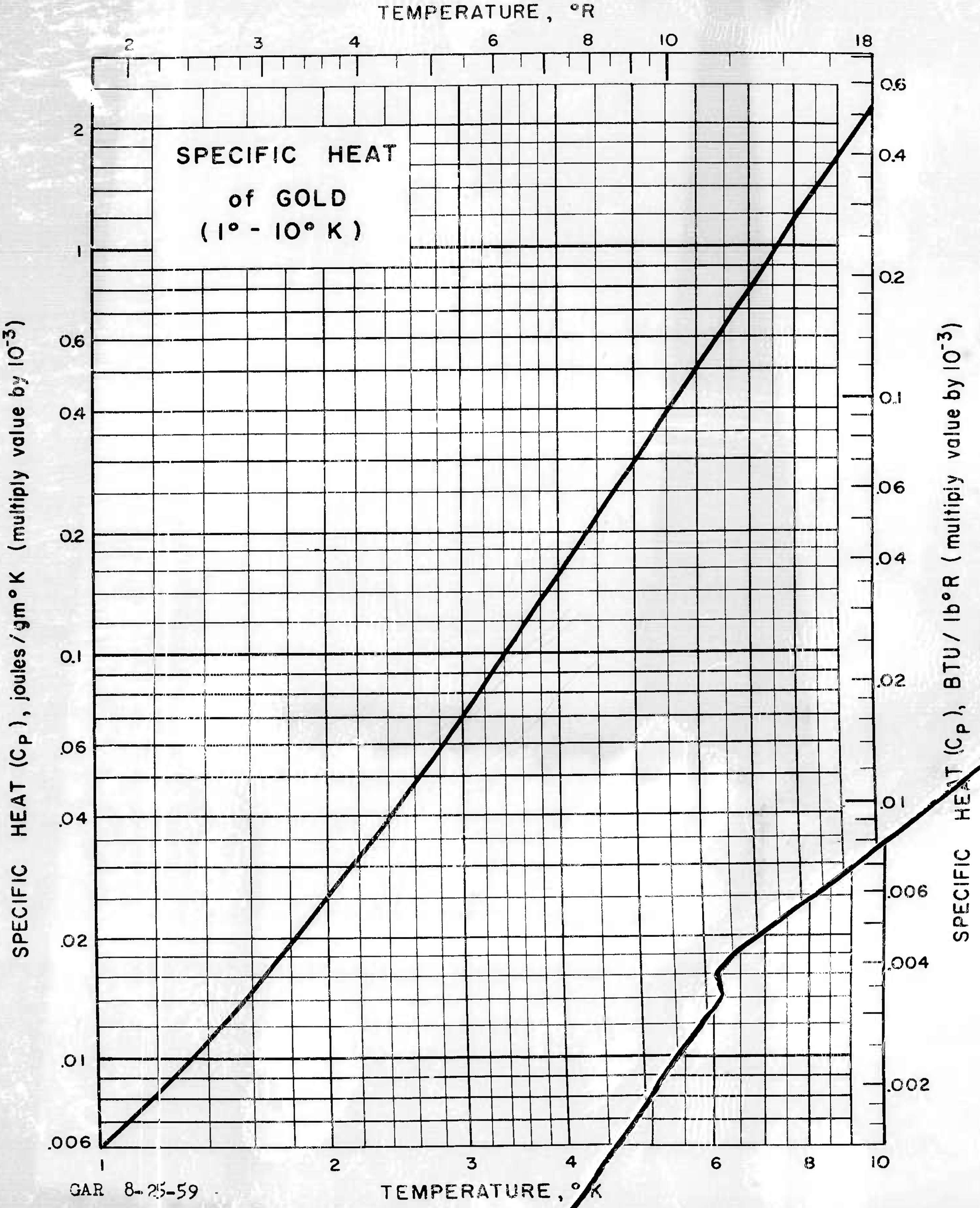
For $0 < T \leq 15$°K, the values for specific heat in the table of selected values below are given by the equation:

$$C_p = 9.86 \, (T/165)^3 + 3.75 \times 10^{-6} \, T \text{ j/gm-°K}$$

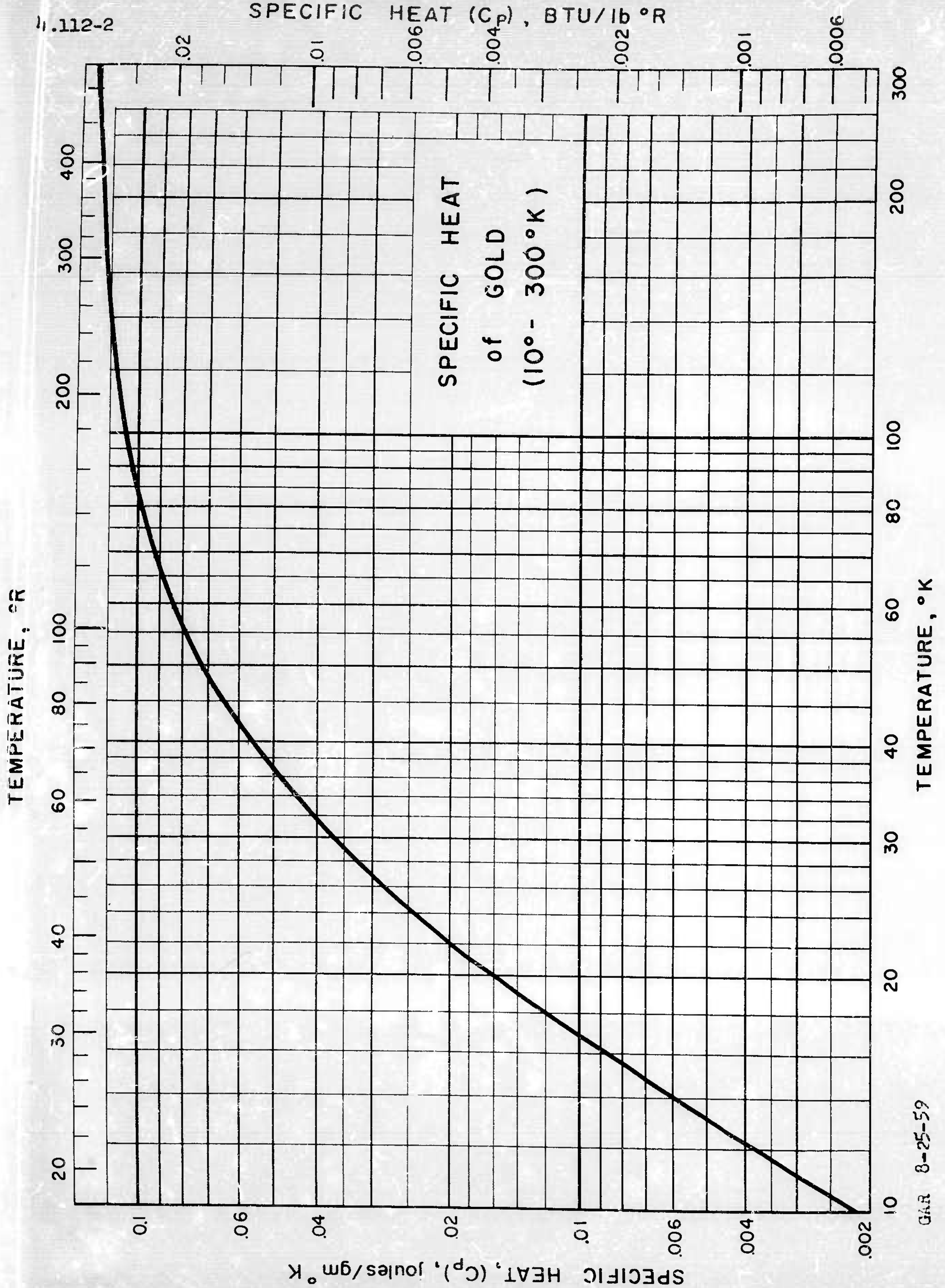
Table of Selected Values

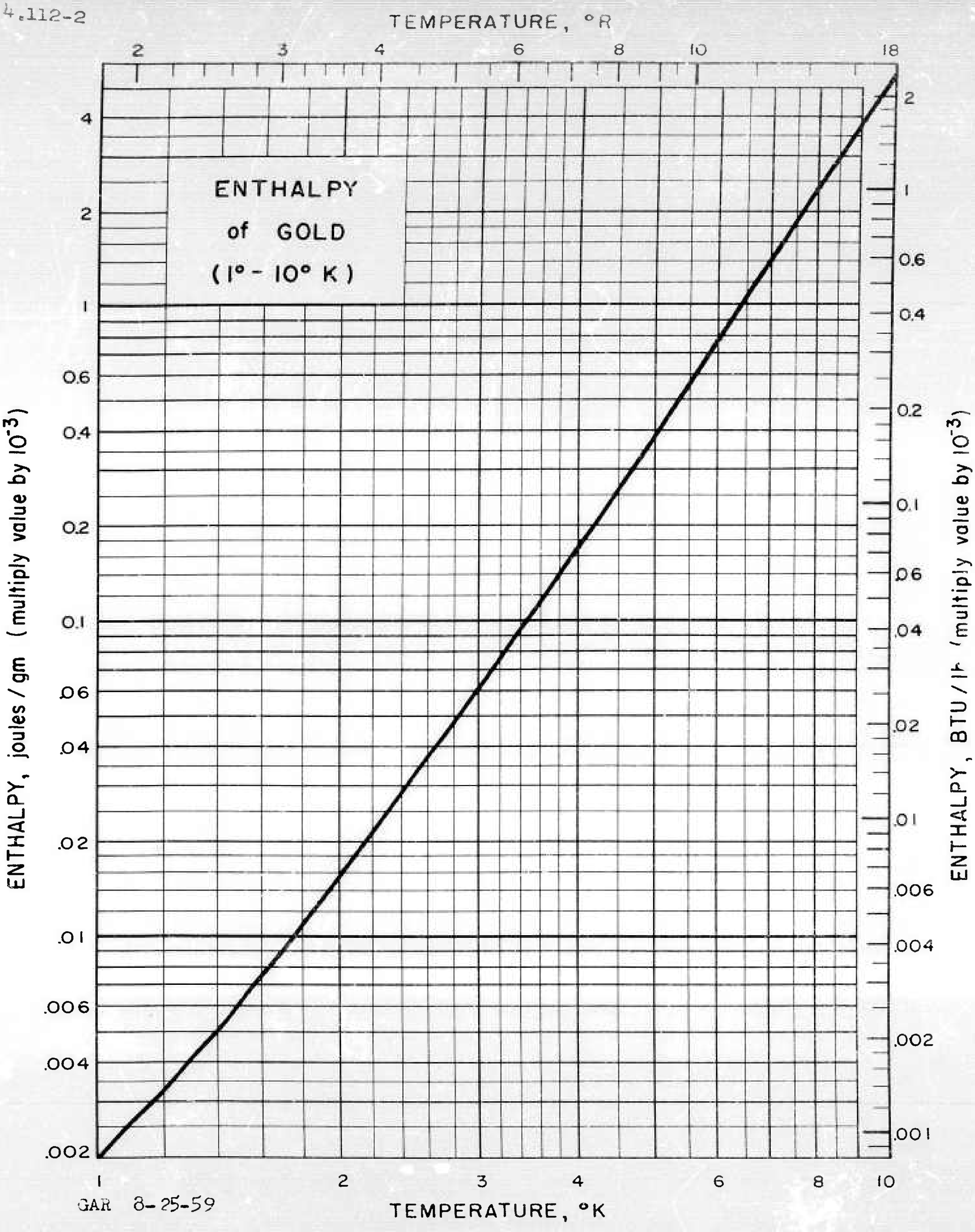
Temp. °K	C_p j/gm-°K	H j/gm	Temp. °K	C_p j/gm-°K	H j/gm
1	0.000 006	0.000 002	70	0.0928	3.14
2	.000 025	.000 016	80	.0992	4.10
3	.000 070	.000 061	90	.1043	5.12
4	.000 16	.000 17	100	.1083	6.18
6	.000 50	.000 78	120	.1137	8.41
8	.001 2	.002 4	140	.1175	10.72
10	.002 2	.005 6	160	.1202	13.10
15	.007 4	.028	180	.1221	15.52
20	.015 9	.086	200	.1235	17.98
25	.026 3	.191	220	.1247	20.46
30	.037 1	.349	240	.1257	22.96
40	.057 2	.821	260	.1267	25.49
50	.072 6	1.47	280	.1276	28.03
60	.084 2	2.25	300	.1285	30.59

RJC/JJG Issued: 10-21-59
Revised: 5-20-60

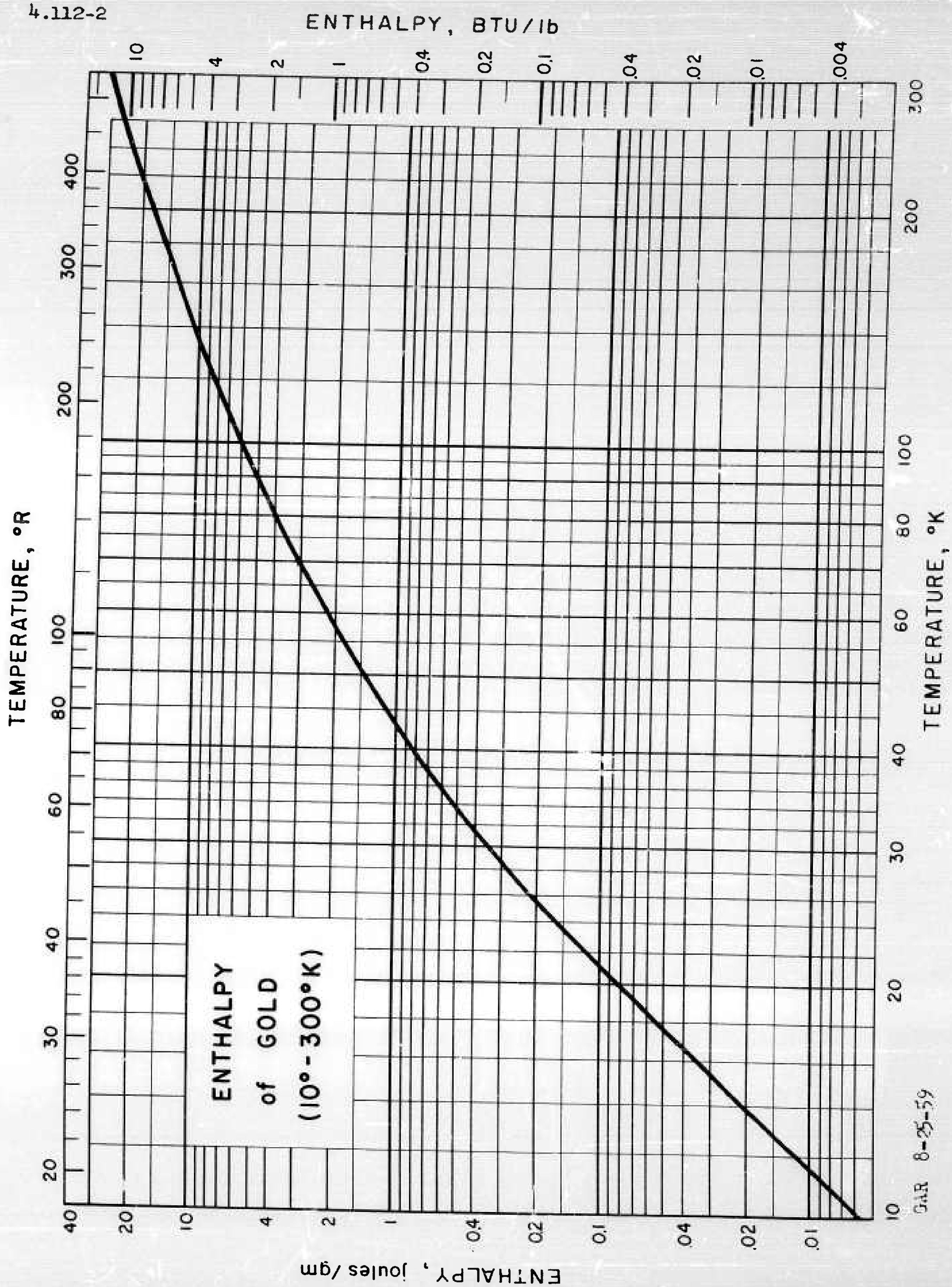

TEMPERATURE, °R
2
3
4
6
8
10
18
SPECIFIC HEAT
of GOLD
(1° - 10° K)
SPECIFIC HEAT (C_p), joules/gm°K (multiply value by 10^{-3})
2
1
0.6
0.4
0.2
0.1
.06
.04
.02
.01
.006
SPECIFIC HEAT (C_p), BTU/lb°R (multiply value by 10^{-3})
0.6
0.4
0.2
0.1
.06
.04
.02
.01
.006
.004
.002
1
2
3
4
6
8
10
TEMPERATURE, °K

GAR 8-25-59


SPECIFIC HEAT (Cp), BTU/lb °R
.02
.01
.006
.004
.002
.001
.0006
SPECIFIC HEAT of GOLD (10° - 300°K)
TEMPERATURE, °R
20
30
40
60
80
100
200
300
400
TEMPERATURE, °K
10
20
30
40
60
80
100
200
300
SPECIFIC HEAT, (Cp), joules/gm °K
0.1
.06
.04
.02
.01
.006
.004
.002
GAR 8-25-59


TEMPERATURE, °R
2
3
4
6
8
10
18
ENTHALPY
of GOLD
(1° - 10° K)
ENTHALPY, joules / gm (multiply value by 10^{-3})
4
2
1
0.6
0.4
0.2
0.1
.06
.04
.02
.01
.006
.004
.002
ENTHALPY, BTU / lb (multiply value by 10^{-3})
2
1
0.6
0.4
0.2
0.1
.06
.04
.02
.01
.006
.004
.002
.001
1
2
3
4
6
8
10
TEMPERATURE, °K

GAR 8-25-59


ENTHALPY, BTU/lb
10
4
2
1
0.4
0.2
0.1
.04
.02
.01
.004
TEMPERATURE, °R
20
30
40
60
80
100
200
300
400
TEMPERATURE, °K
10
20
30
40
60
80
100
200
300
ENTHALPY, joules/gm
40
20
10
4
2
1
0.4
0.2
0.1
.04
.02
.01
ENTHALPY of GOLD (10°-300°K)
GAR 8-25-59

SPECIFIC HEAT, ENTHALPY of SILVER

Sources of Data:

Corak, W. S., Garfunkel, M. P., Satterthwaite, C. B. and Wexler, A., Phys. Rev. 98, 1699 (1955)
Meads, P. F., Forsythe, W. R. and Giauque, W. F., J. Am. Chem. Soc. 63, 1902 (1941)

Other References:

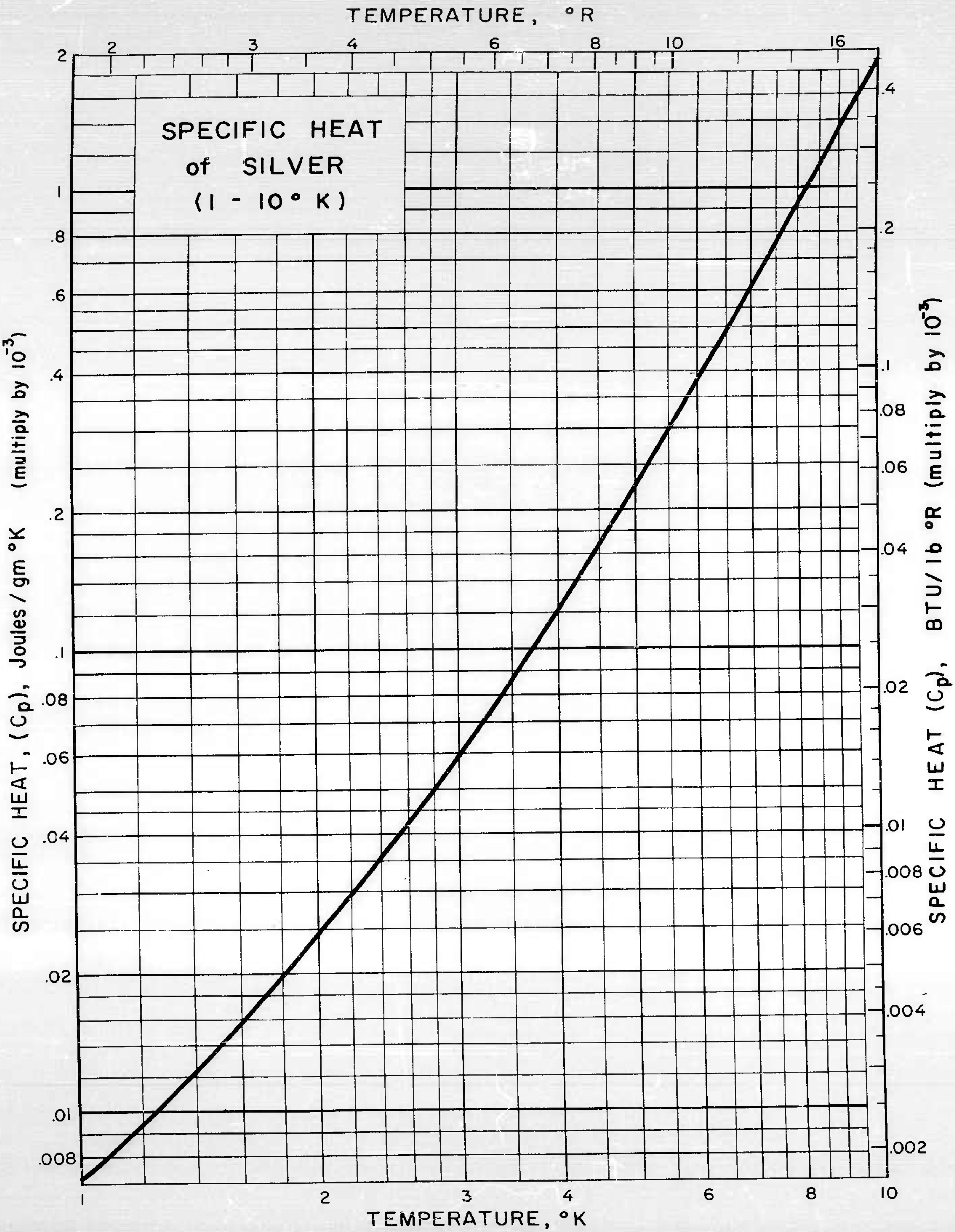
Barchall, H., Z. Electrochem. 17, 341 (1911)
Bronson, H. L. and Wilson, A. J. C., Can. J. Research, A14, 181 (1936)
Eucken, A., Clusius, K. and Woiteneck, H., Z. anorg. allgem. Chemie 203, 39 (1931)
Griffiths, E. G. and Griffiths, E., Proc. Roy. Soc. (London) A90, 557 (1914)
Keesom, W. H., Z. ges. Kalte-Ind. 40, 49 (1933)
Keesom, W. H., J. phys. radium (7) 5, 373 (1934)
Keesom, W. H. and Kok, J. A., Proc. Acad. Sci. Amsterdam 35, 301 (1932)
Keesom, W. H. and Kok, J. A., Physica 1, 770 (1934)
Keesom, W. H. and Pearlman, N., Phys. Rev. 98, 548 (1955)
Mendelsohn, K. and Closs, J. O., Z. physik. Chem. B19, 291 (1932)
Nernst, W., Sitzber. kgl. preuss. Akad. Wiss. 262 (1910)
Nernst, W., Ann. Physik (4) 36, 395 (1911)
Nernst, W. and Lindemann, F. A., Sitzber. kgl. preuss. Akad. Wiss. 494 (1911)
Rayne, J. A., Phys. Rev. 95, 1428 (1954)
Richards, T. W. and Jackson, F. G., Z. physik. Chem. 70, 414 (1910)
Schmitz, H. E., Proc. Roy. Soc. (London) 72, 177 (1903)
Tilden, W. A., Proc. Roy. Soc. (London) 71, 220 (1903)
Hoare, F. E. and Yates, B., Proc. Roy. Soc. (London) A240, 42 (1957)

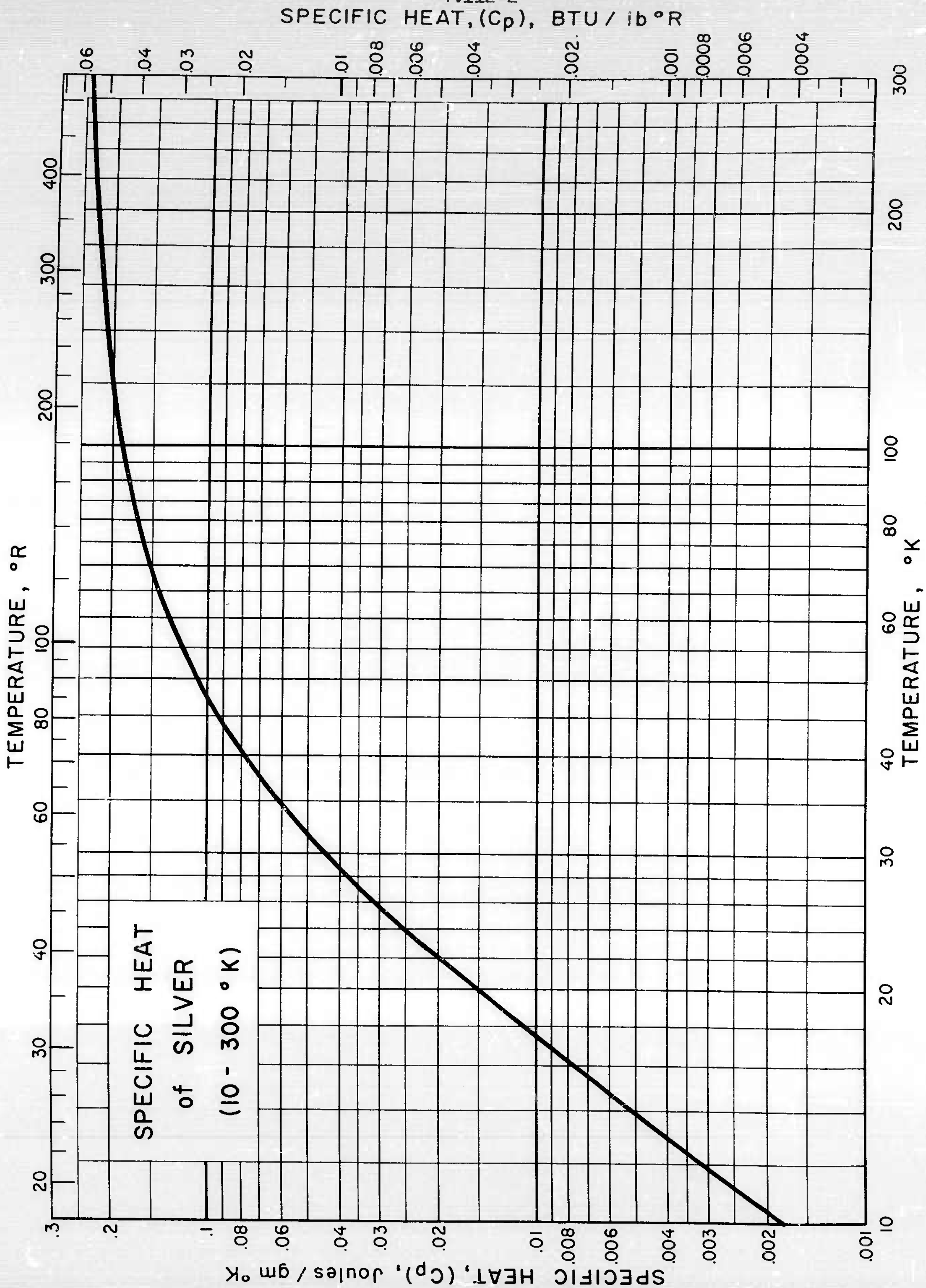
Table of Selected Values

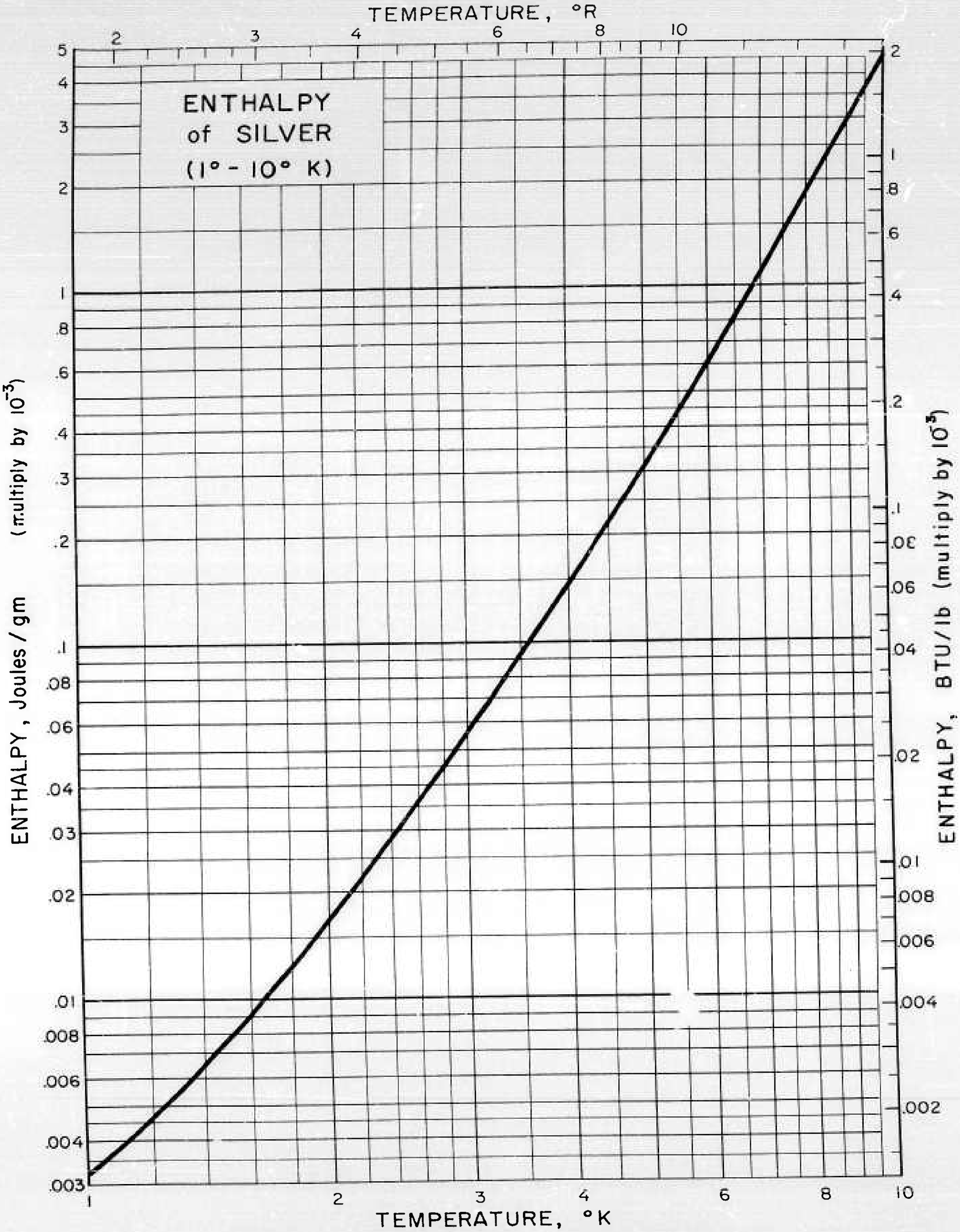
T °K	Cp j/gm-°K	H j/gm
1	0.000 0072	0.000 0032
2	.000 0239	.000 0176
3	.000 0595	.000 0574
4	.000 124	.000 146
6	.000 39	.000 62
8	.000 91	.001 87
10	.001 8	.004 52
15	.006 4	.023 3
20	.015 5	.076
25	.028 7	.185
30	.044 2	.368
40	.078	.979
50	.108	1.91
60	.133	3.12

T °K	Cp j/gm-°K	H j/gm
70	0.151	4.54
80	.166	6.13
90	.177	7.85
100	.187	9.67
120	.200	13.55
140	.209	17.65
160	.216	21.91
180	.221	26.29
200	.225	30.75
220	.228	35.28
240	.231	39.86
260	.234	44.50
280	.235	49.20
300	.236	53.91

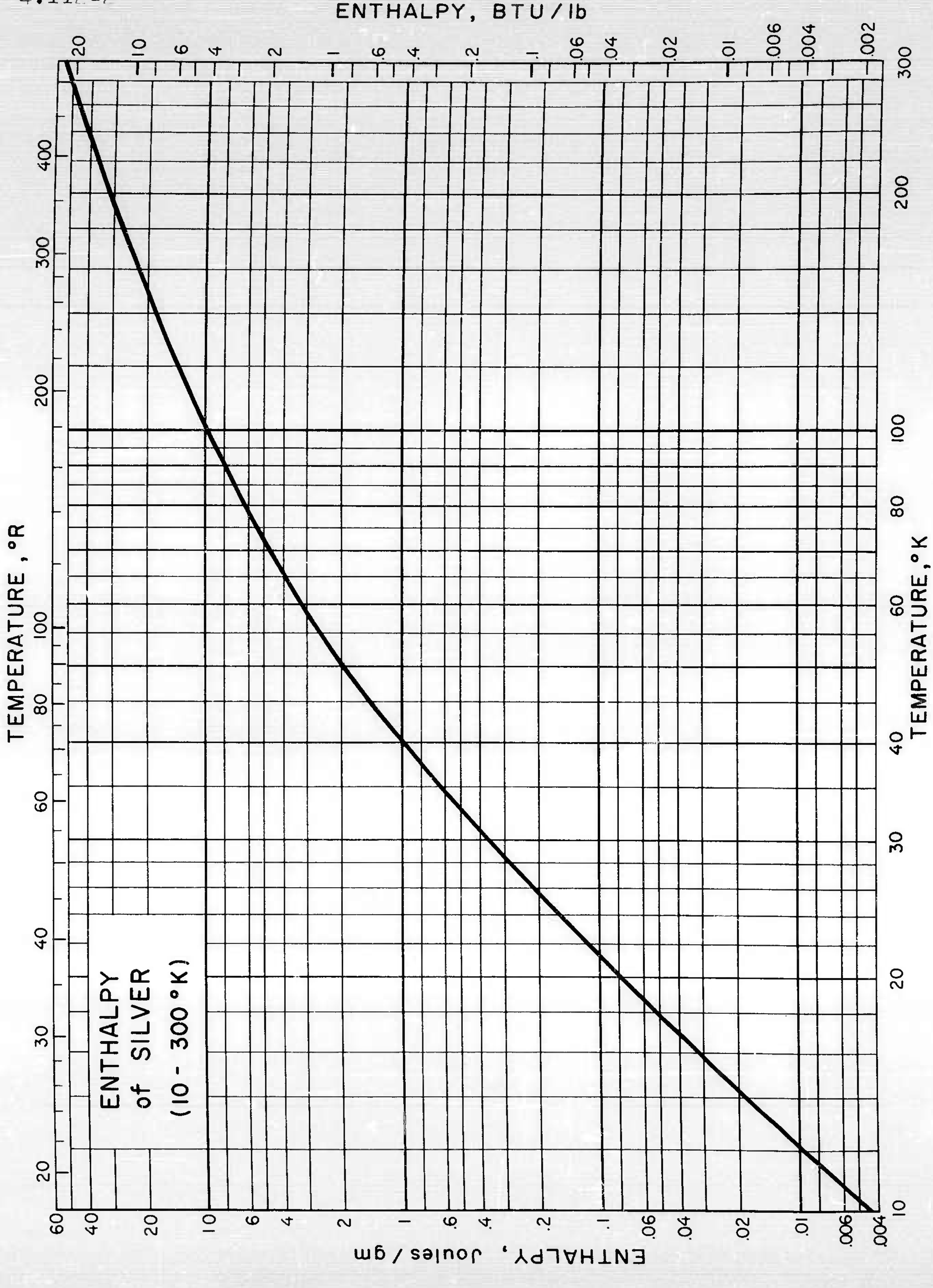
RJC Issued: 6-15-59
Revised: 5-20-60


TEMPERATURE, °R
2
3
4
6
8
10
16
SPECIFIC HEAT
of SILVER
(1 - 10° K)
SPECIFIC HEAT, (C_p), Joules / gm °K (multiply by 10^{-3})
SPECIFIC HEAT (C_p), BTU/lb °R (multiply by 10^{-3})
2
1
.8
.6
.4
.2
.1
.08
.06
.04
.02
.01
.008
.4
.2
.1
.08
.06
.04
.02
.01
.008
.006
.004
.002
1
2
3
4
6
8
10
TEMPERATURE, °K


SPECIFIC HEAT, (Cp), BTU / lb °R
SPECIFIC HEAT of SILVER (10 - 300 °K)
TEMPERATURE, °R
TEMPERATURE, °K
SPECIFIC HEAT, (Cp), Joules / gm °K



TEMPERATURE, °R
2
3
4
6
8
10
ENTHALPY
of SILVER
(1° - 10° K)
ENTHALPY, Joules / gm (multiply by 10^{-3})
5
4
3
2
1
.8
.6
.4
.3
.2
.1
.08
.06
.04
.03
.02
.01
.008
.006
.004
.003
ENTHALPY, BTU/lb (multiply by 10^{-3})
2
1
.8
.6
.4
.2
.1
.08
.06
.04
.02
.01
.008
.006
.004
.002
1
2
3
4
6
8
10
TEMPERATURE, °K


ENTHALPY, BTU/lb
20
10
6
4
2
1
.6
.4
.2
.1
.06
.04
.02
.01
.006
.004
.002
TEMPERATURE, °R
400
300
200
100
80
60
40
30
20
TEMPERATURE, °K
300
200
100
80
60
40
30
20
10
ENTHALPY of SILVER (10 - 300 °K)
ENTHALPY, Joules/gm
60
40
20
10
6
4
2
1
.6
.4
.2
.1
.06
.04
.02
.01
.006
.004

SPECIFIC HEAT, ENTHALPY of BERYLLIUM

Source of Data:

Hill, R. W. and Smith, P. L., Phil. Mag. 44, 636-44 (1953)

Other References:

Cristescu, S. and Simon, F., Z. physik. Chem. B25, 273 (1934)

Kelley, K. K., U.S. Bur. Mines Bull. No. 476 (1949)

Lewis, E. J., Phys. Rev. (2) 34, 1575 (1929)

Simon, F. and Ruhemann, M., Z. physik. Chem. 129, 321 (1927)

Comments:

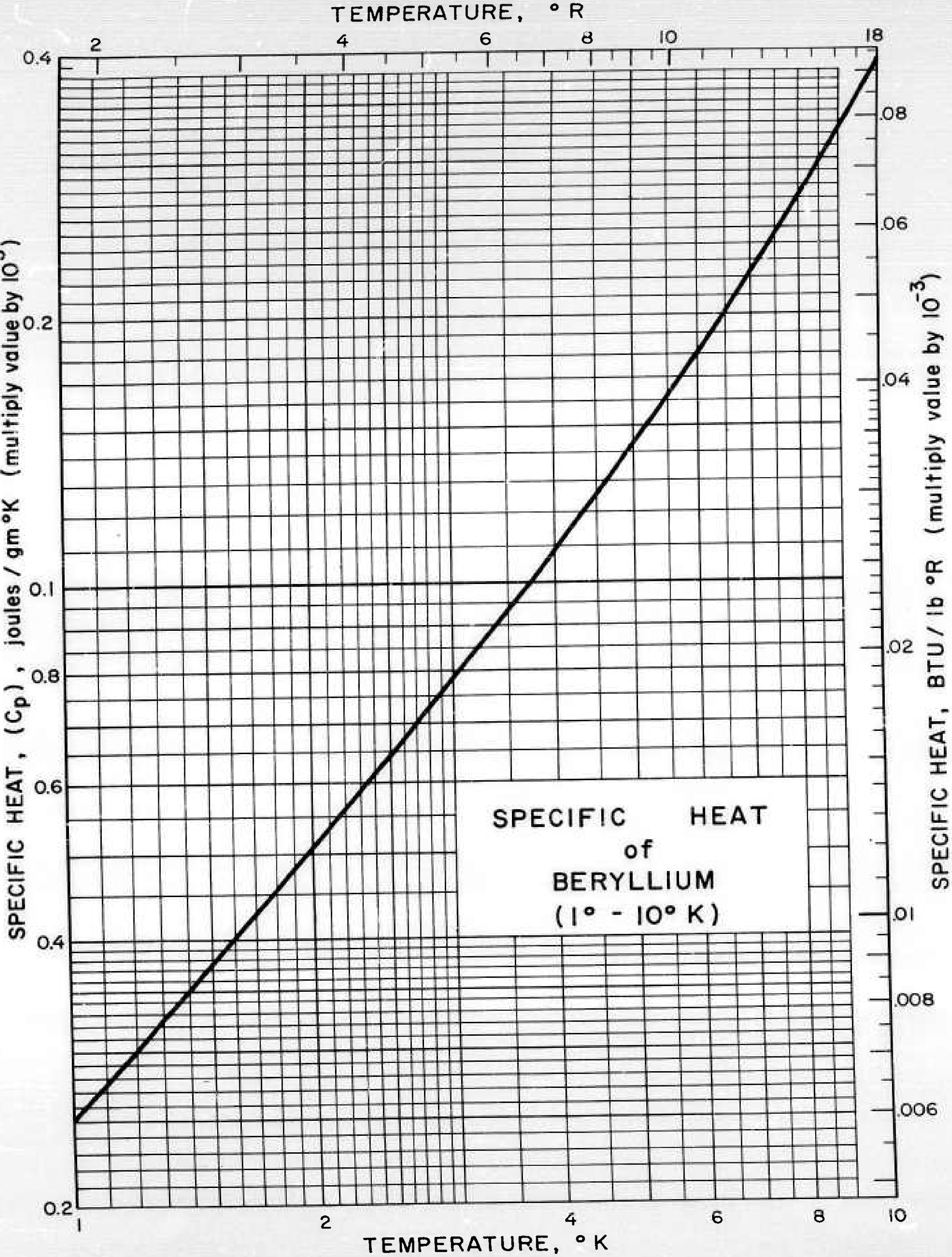
For the temperature range from 0° to 20°K, the specific heat C_p follows the equation:

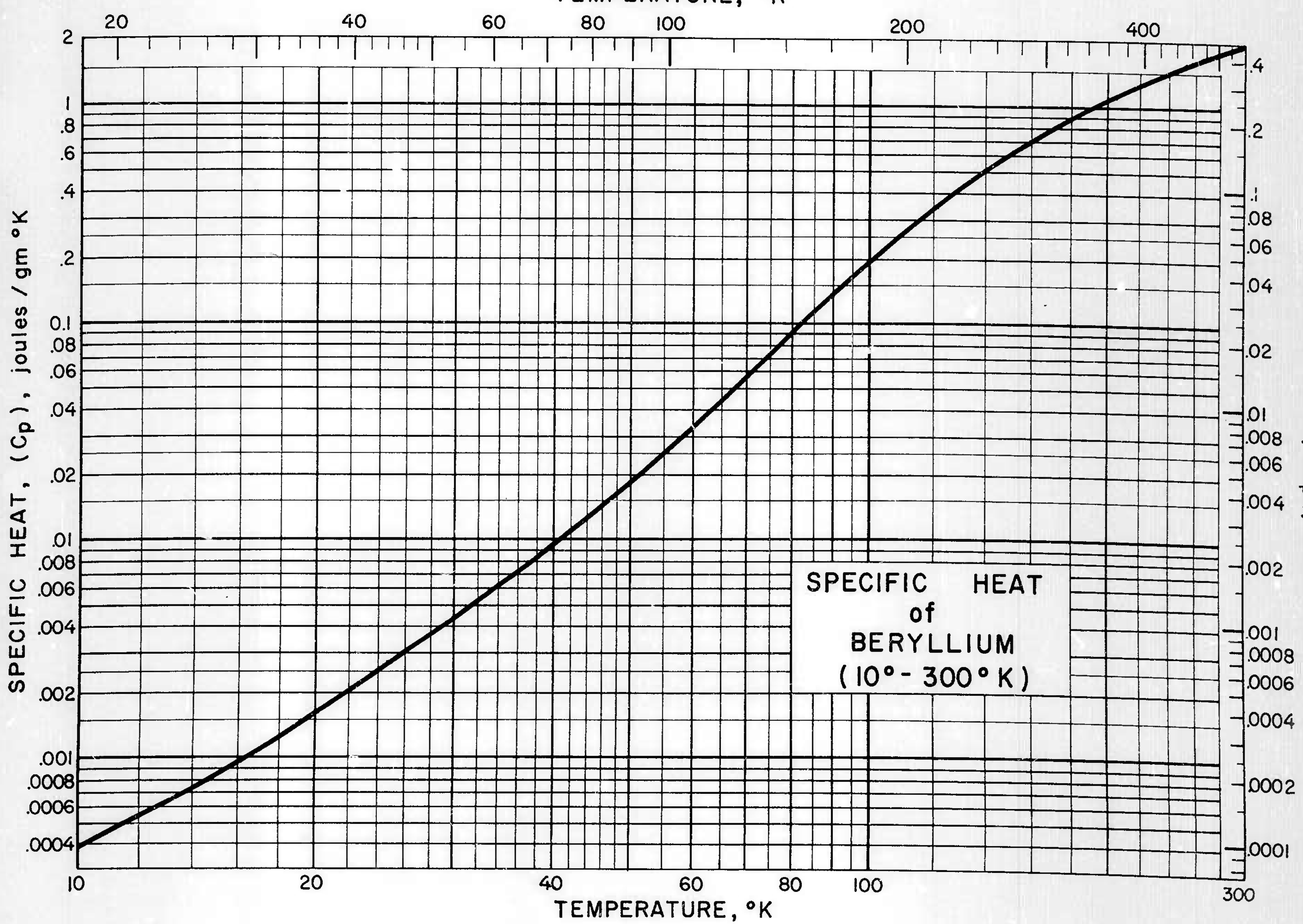
$$C_p = (2.5\pm0.4) \times 10^{-5}T + 215.7 \left(\frac{T}{1160\pm5}\right)^3 \text{ j/gm-°K}$$

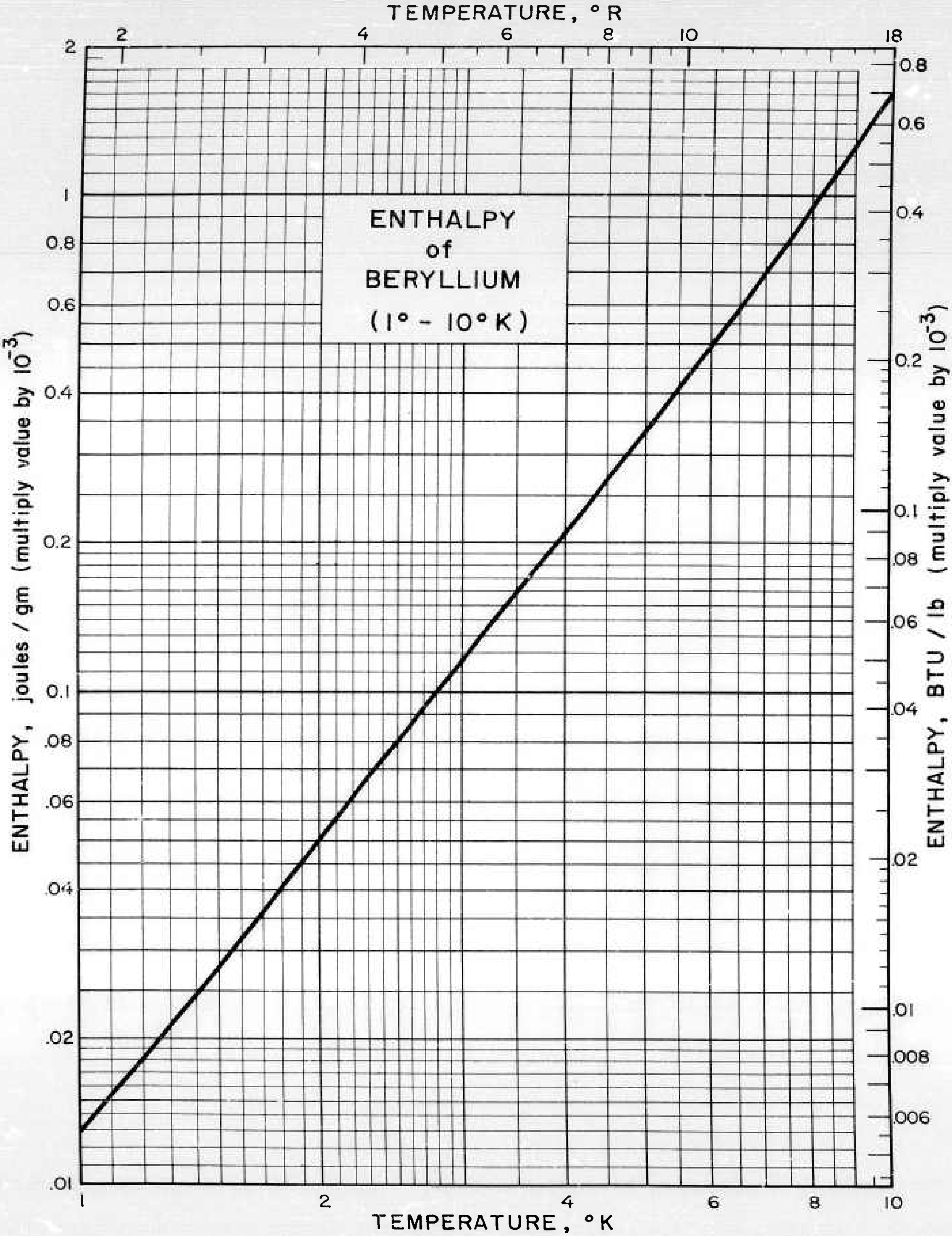
Table of Selected Values

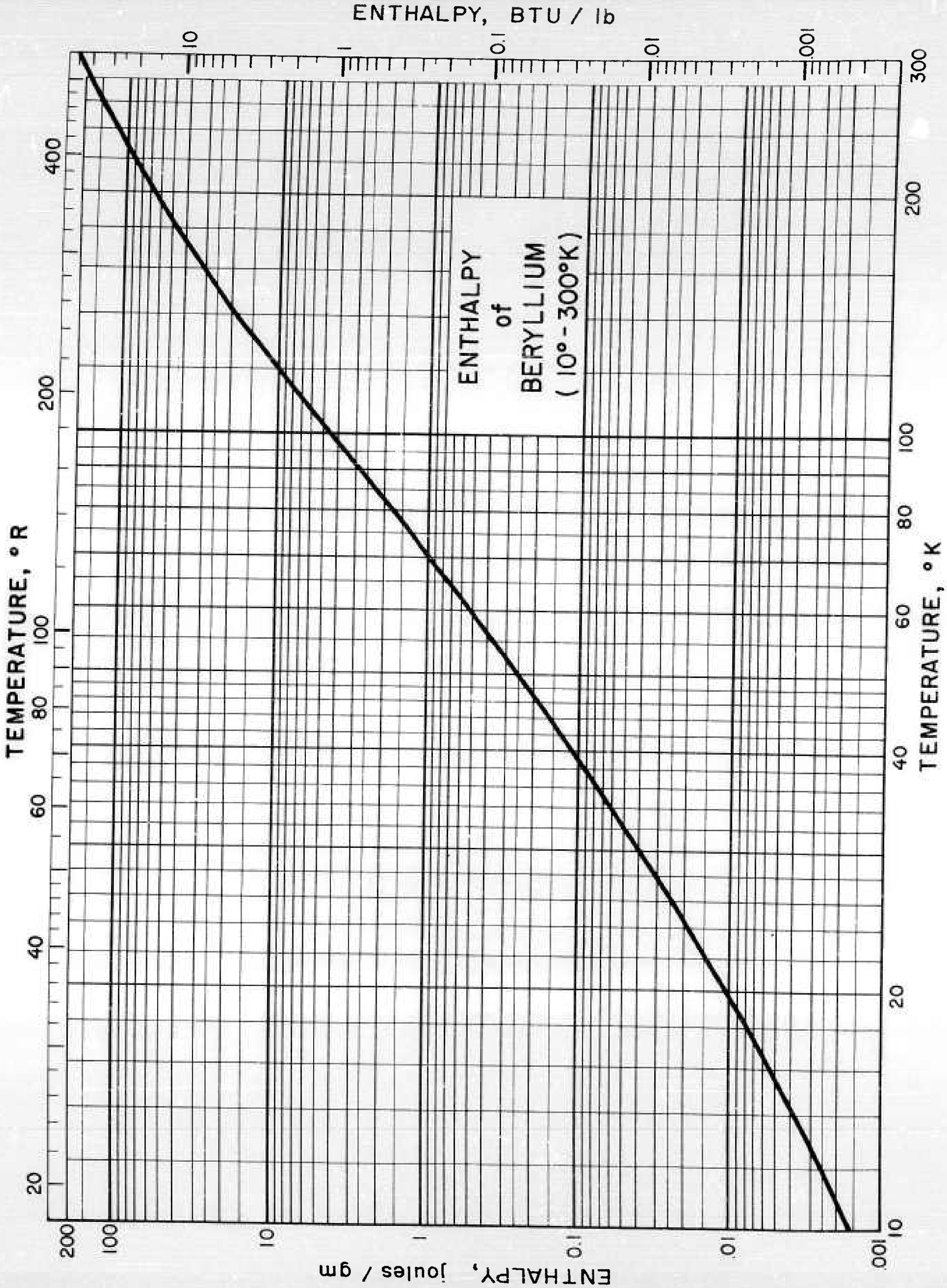
Temp. °K	C_p j/gm-°K	H j/gm	Temp. °K	C_p j/gm-°K	H j/gm
1	0.000 025	0.000 013	70	0.0562	0.971
2	.000 051	.000 051	80	.0906	1.69
3	.000 079	.000 116	90	.139	2.82
4	.000 109	.000 209	100	.199	4.51
6	.000 180	.000 496	120	.345	9.87
8	.000 271	.000 944	140	.525	18.5
10	.000 389	.001 60	160	.723	31.0
15	.000 842	.004 57	180	.921	47.4
20	.001 61	.010 5	200	1.11	67.8
25	.002 79	.021 2	220	1.29	91.8
30	.004 50	.039 2	240	1.47	120
40	.009 96	.109	260	1.64	151
50	.019 2	.253	280	1.81	185
60	.034 1	.523	300	1.97	223

RJC/JJG Issued: 10-13-59


TEMPERATURE, °R
2
4
6
8
10
18
0.4
0.2
0.1
0.8
0.6
0.4
0.2
.08
.06
.04
.02
.01
.008
.006
SPECIFIC HEAT, (C_p), joules / gm°K (multiply value by 10^{-3})
SPECIFIC HEAT, BTU / lb °R (multiply value by 10^{-3})
SPECIFIC HEAT
of
BERYLLIUM
(1° - 10° K)
1
2
4
6
8
10
TEMPERATURE, °K


TEMPERATURE, °R
20
40
60
80
100
200
400
SPECIFIC HEAT, (Cp), joules / gm °K
2
1
.8
.6
.4
.2
0.1
.08
.06
.04
.02
.01
.008
.006
.004
.002
.001
.0008
.0006
.0004
SPECIFIC HEAT, (Cp), BTU / lb °R
.4
.2
.1
.08
.06
.04
.02
.01
.008
.006
.004
.002
.001
.0008
.0006
.0004
.0002
.0001
SPECIFIC HEAT
of
BERYLLIUM
(10° - 300° K)
10
20
40
60
80
100
300
TEMPERATURE, °K


TEMPERATURE, °R
2
4
6
8
10
18
2
1
0.8
0.6
0.4
0.2
0.1
.08
.06
.04
.02
.01
ENTHALPY of BERYLLIUM (1° - 10° K)
ENTHALPY, joules / gm (multiply value by 10^{-3})
0.8
0.6
0.4
0.2
0.1
.08
.06
.04
.02
.01
.008
.006
ENTHALPY, BTU / lb (multiply value by 10^{-3})
1
2
4
6
8
10
TEMPERATURE, °K


ENTHALPY, BTU / lb
ENTHALPY of BERYLLIUM (10°-300°K)
TEMPERATURE, °R
TEMPERATURE, °K
ENTHALPY, joules / gm

SPECIFIC HEAT, ENTHALPY of MAGNESIUM

Sources of Data:

Craig, R. S., Krier, C. A., Coffer, L. W., Bates, E. A. and Wallace, W. E., J. Am. Chem. Soc. 76, 238 (1954)

Smith, P. L., Phil. Mag. (7) 46, 744 (1955)

Other References:

Clusius, K. and Vaughen, J. V., J. Am. Chem. Soc. 52, 4686 (1930)

Eastman, E. C. and Rodebush, W. H., J. Am. Chem. Soc. 40, 489 (1918)

Estermann, I., Friedberg, S. A. and Goldman, J. E., Phys. Rev. 87, 582 (1952)

Friedberg, S. A., Estermann, I. and Goldman, J. E., Phys. Rev. 85, 375-6 (1952)

Ewald, R., Ann. Physik (4) 44, 1213 (1914)

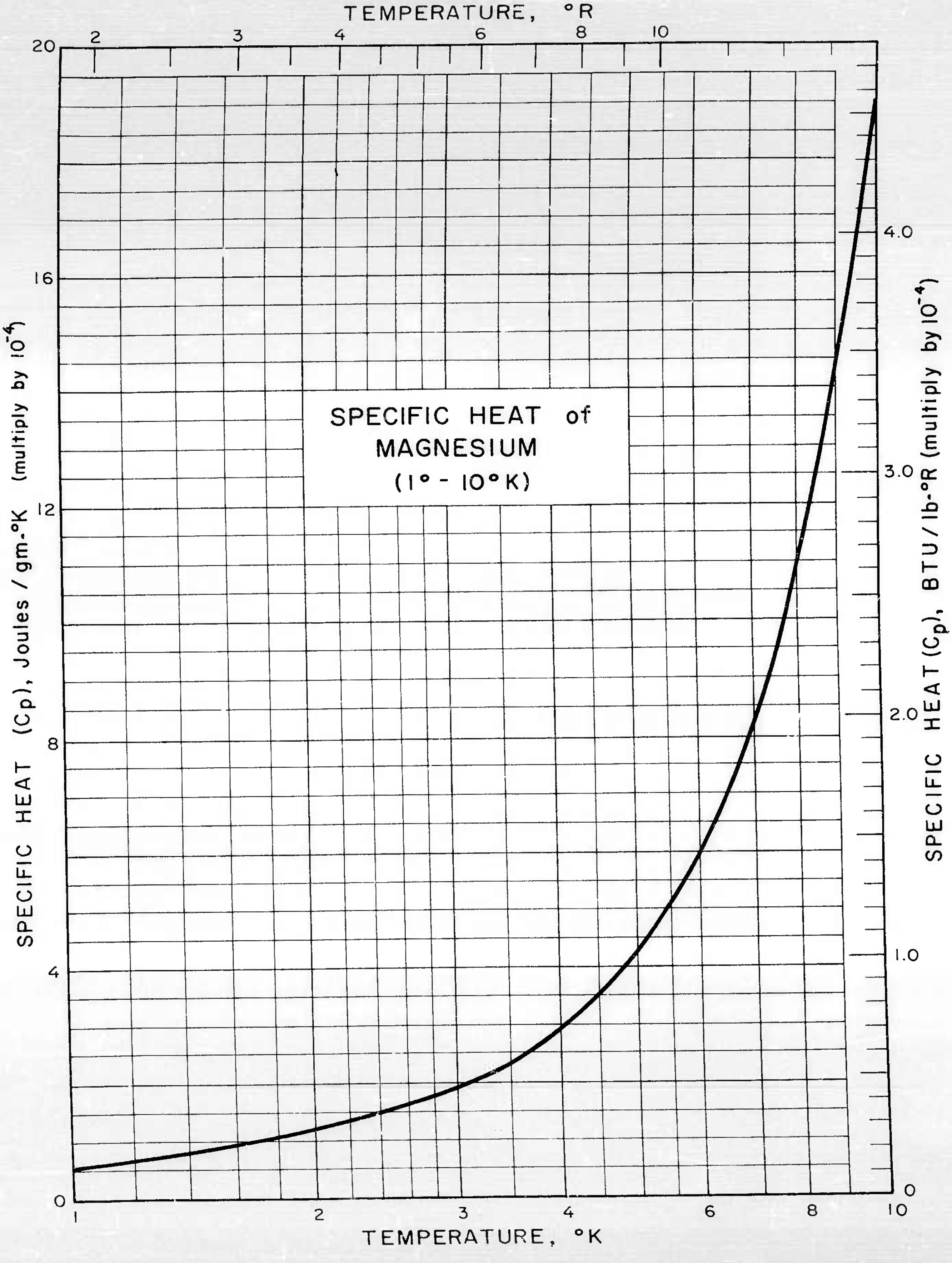
Nernst, W. and Schwers, F., Sitzber. kgl. preuss. Akad. Wiss. 355, (1914)

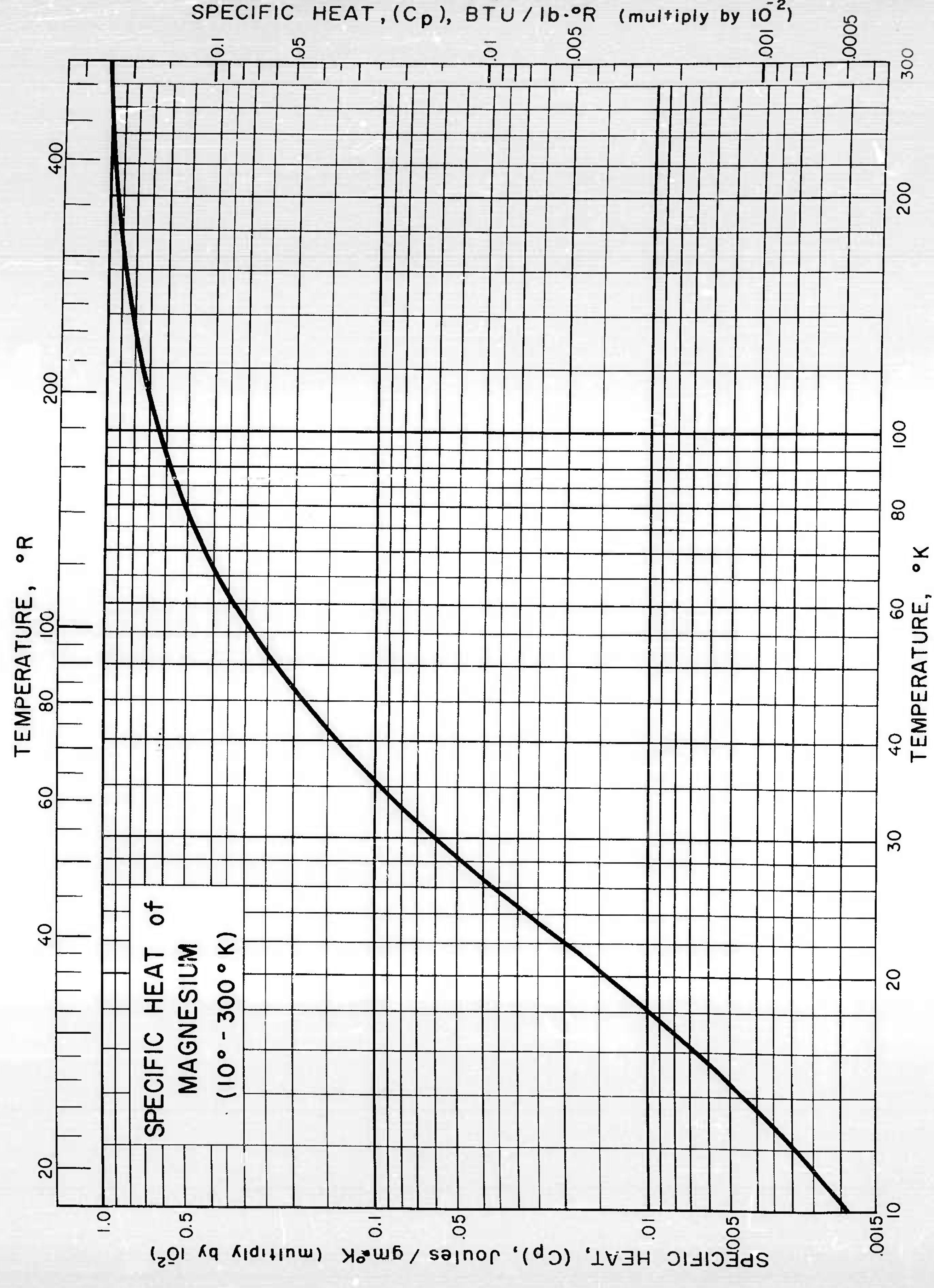
Richards, T. W. and Jackson, F. G., Z. physik. Chem. 70, 414 (1910)

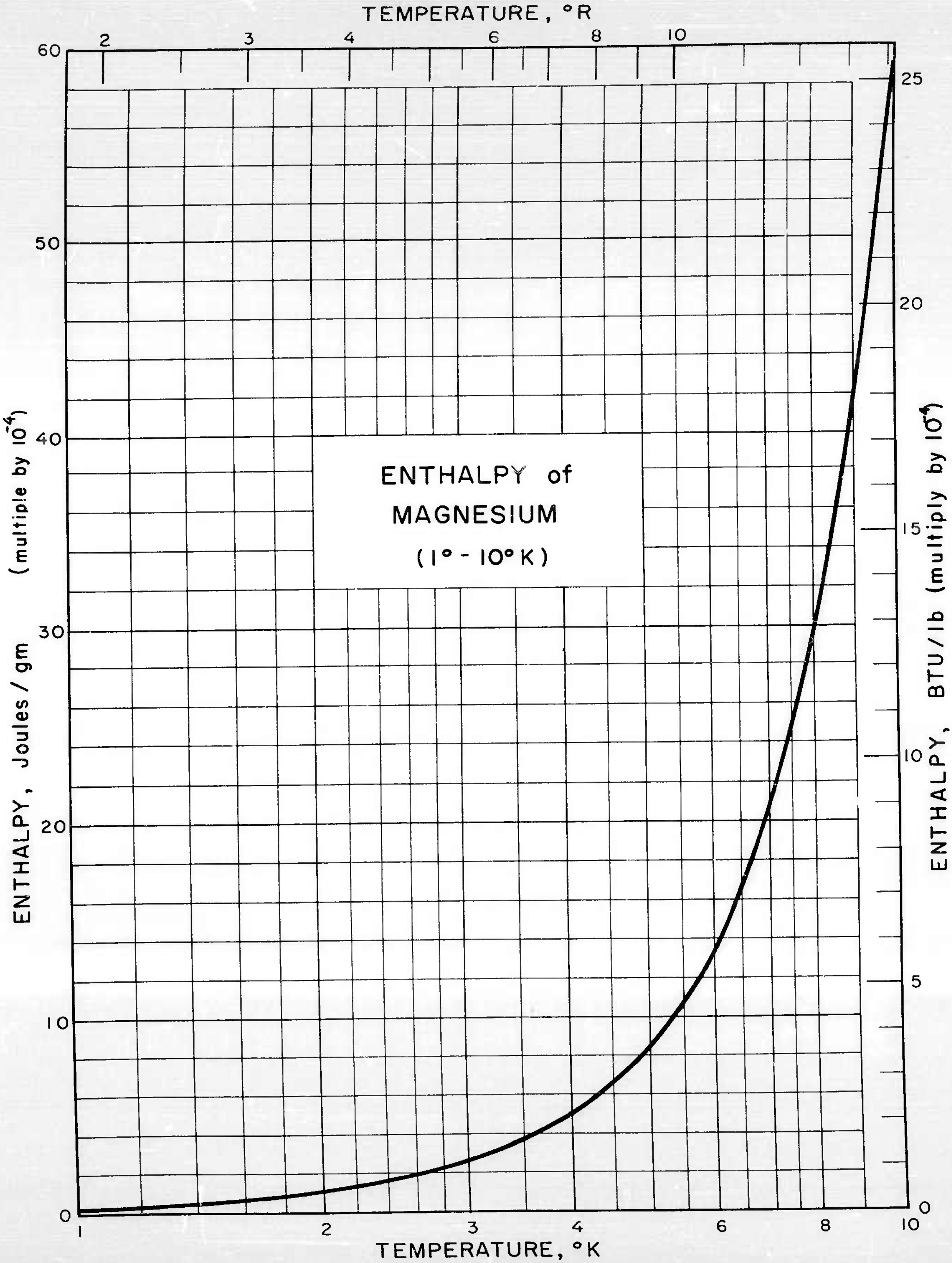
Table of Selected Values

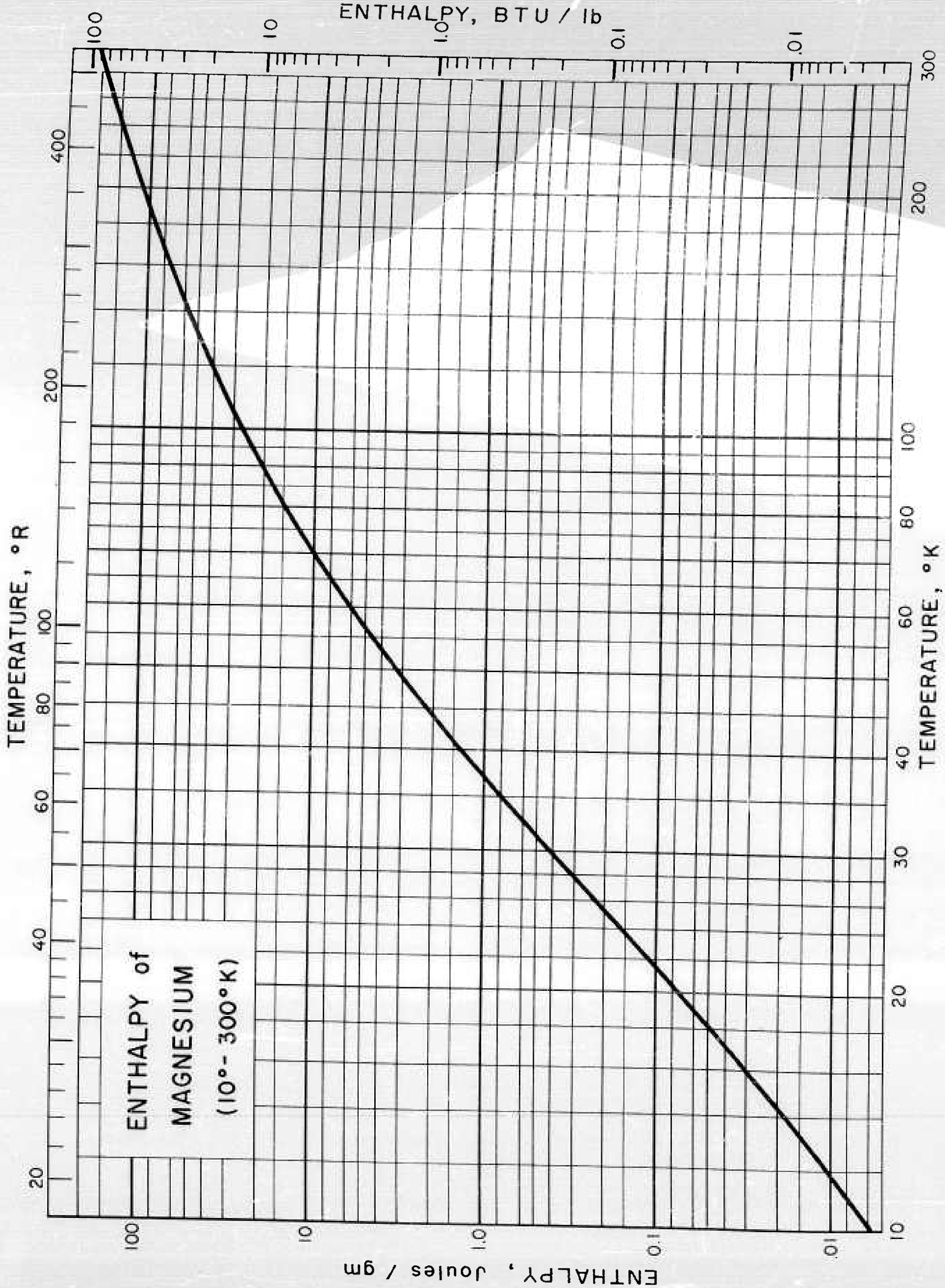
Temp. °K	C_p j/gm °K	H j/gm	Temp. °K	C_p j/gm °K	H j/g
1	0.000 055	0.000 027	70	0.430	9.9
2	.000 117	.000 112	80	.513	14.6
3	.000 19	.000 26	90	.586	20.1
4	.000 29	.000 50	100	.646	26.3
6	.000 59	.001 36	120	.741	40.2
8	.001 08	.003 00	140	.812	55.8
10	.001 9	.005 9	160	.862	72.5
15	.005 8	.023 7	180	.901	90.2
20	.015	.074	200	.932	108.5
25	.032	.189	220	.955	127.4
30	.059	.415	240	.975	146.7
35	.095	.795	260	.992	166.4
40	.138	1.37	280	1.007	186.4
50	.235	3.23	300	1.021	206.7
60	.336	6.10			

RJC Issued: 12-10-59
Revised: 5-20-60


TEMPERATURE, °R
2
3
4
6
8
10
20
16
12
8
4
0
SPECIFIC HEAT of
MAGNESIUM
(1° - 10° K)
SPECIFIC HEAT (Cp), Joules / gm-°K (multiply by 10^-4)
SPECIFIC HEAT (Cp), BTU / lb-°R (multiply by 10^-4)
4.0
3.0
2.0
1.0
0
1
2
3
4
6
8
10
TEMPERATURE, °K


SPECIFIC HEAT, (Cp), BTU / lb·°R (multiply by 10^{-2})
.1
.05
.01
.005
.001
.0005
TEMPERATURE, °R
20
40
60
80
100
200
400
TEMPERATURE, °K
10
20
30
40
60
80
100
200
300
SPECIFIC HEAT of
MAGNESIUM
(10° - 300° K)
SPECIFIC HEAT, (Cp), Joules / gm·°K (multiply by 10^{2})
1.0
0.5
0.1
.05
.01
.005
.0015


TEMPERATURE, °R
2
3
4
6
8
10
60
50
40
30
20
10
0
25
20
15
10
5
0
ENTHALPY of
MAGNESIUM
(1° - 10° K)
ENTHALPY, Joules / gm (multiple by 10^{-4})
ENTHALPY, BTU/lb (multiply by 10^{-4})
1
2
3
4
6
8
10
TEMPERATURE, °K


ENTHALPY, BTU / lb
100
10
1.0
0.1
.01
TEMPERATURE, °R
400
200
100
80
60
40
20
TEMPERATURE, °K
300
200
100
80
60
40
30
20
10
ENTHALPY of
MAGNESIUM
(10°- 300°K)
ENTHALPY, Joules / gm
100
10
1.0
0.1
.01

SPECIFIC HEAT, ENTHALPY of CADMIUM

Sources of Data:

Bronson, H. L. and Wilson, A. J. C., Can. J. Research A14, 181 (1936)

Craig, R. S., Krier, C. A., Coffer, L. W., Bates, E. A. and Wallace, W. E., J. Am. Chem. Soc. 76, 238 (1954)

Smith, P. L., Conference de Physique des Basses Temperatures, Paris 281-3 (1955)

Other References:

Barchall, H., Z. Elektrochem. 17, 341 (1911)

Ewald, R., Ann. Physik. (4) 44, 1213 (1914)

Lange, F. and Simon, F., Z. physik. Chem. 134, 374 (1928)

Richards, T. W. and Jackson, F. G., Z. physik. Chem. 70, 414 (1910)

Rodebush, W. H., J. Am. Chem. Soc. 45, 1413 (1923)

Samoilov, B. N., Doklady Akad. Nauk. S.S.S.R. 86, 281-4 (1952)

Comments:

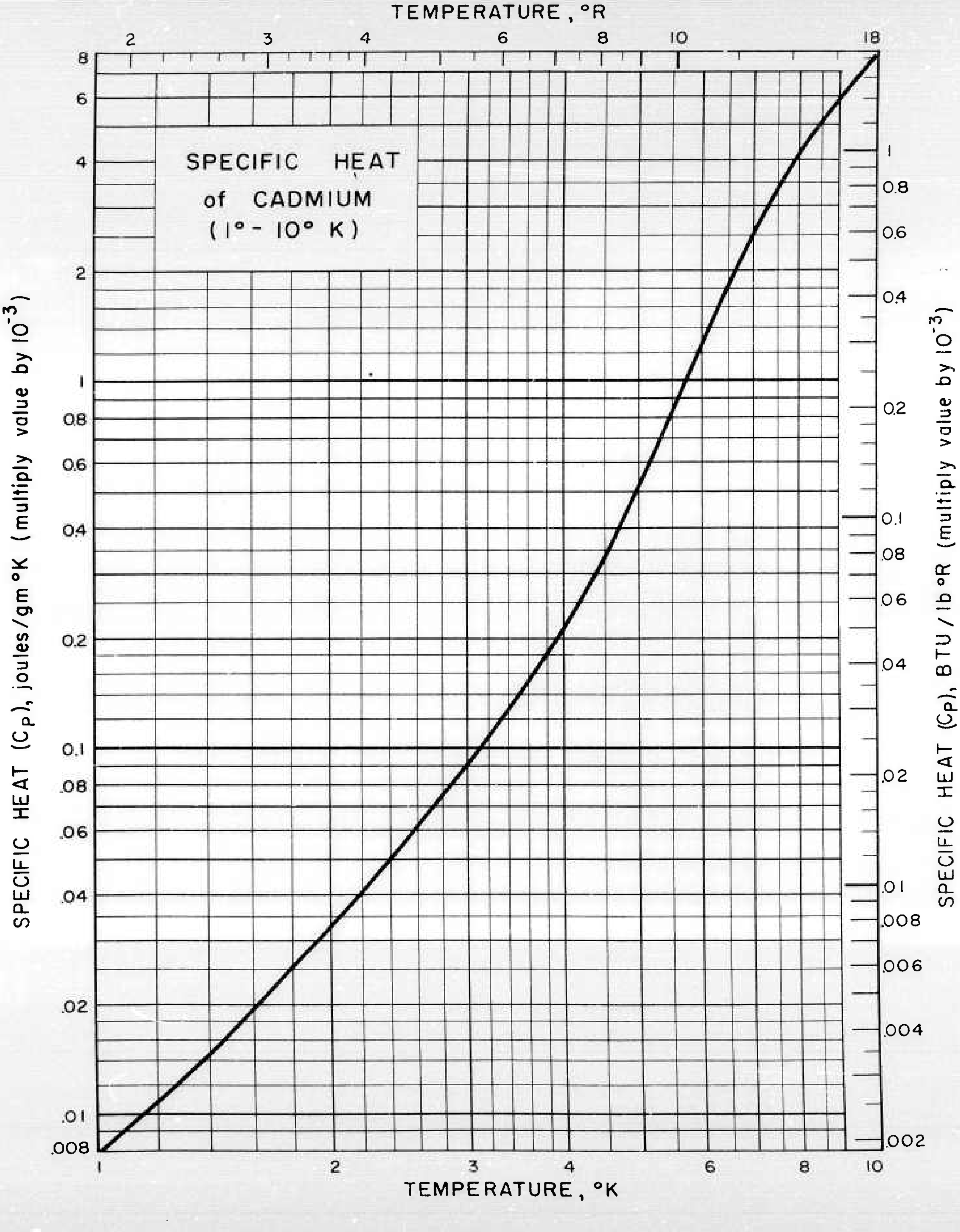
For $0 < T \leq 3°K$

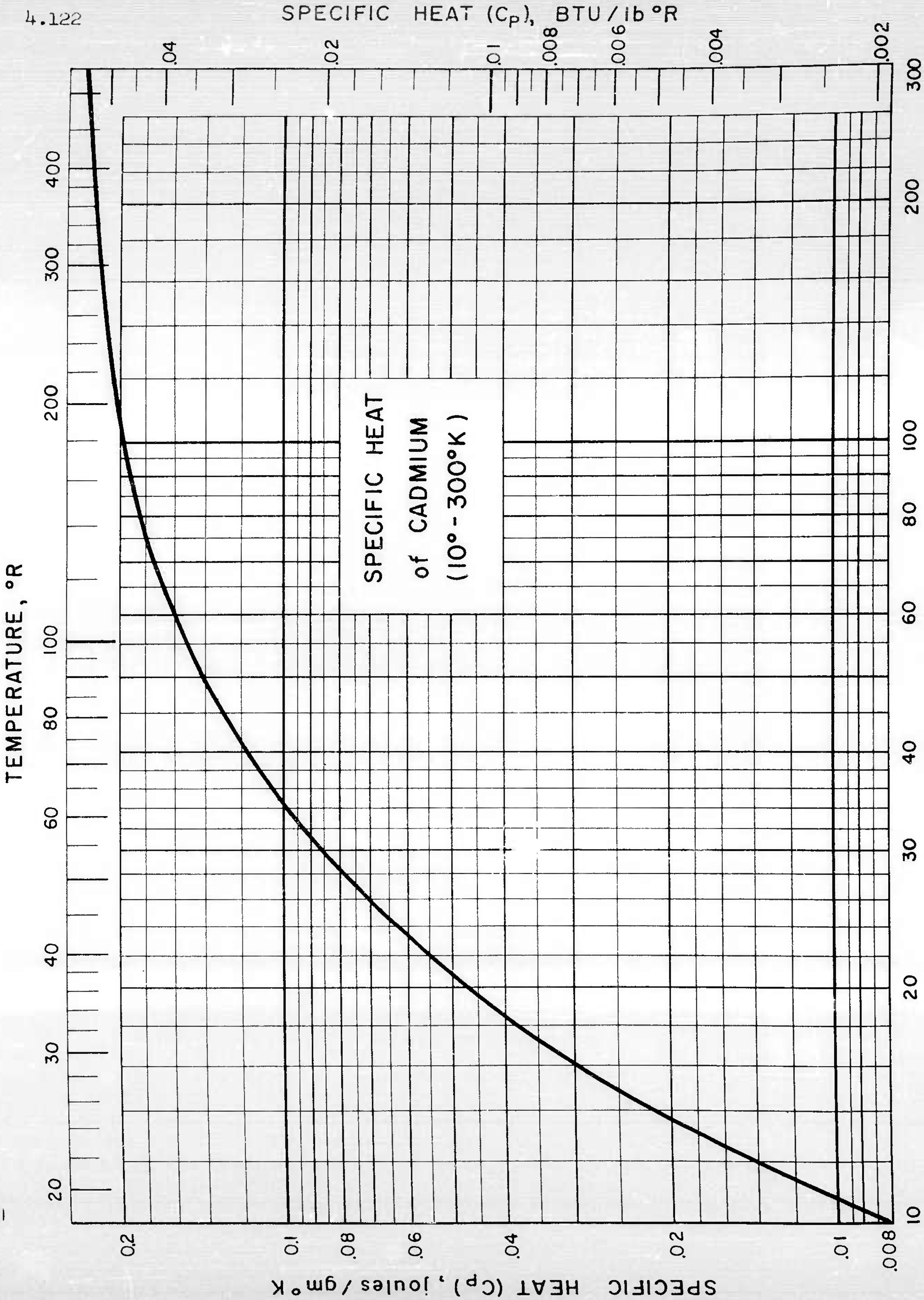
$$C_p = 17.3\ (T/186)^3 \times 5.6 \times 10^{-6}\ T\ \text{j/gm-°K}$$

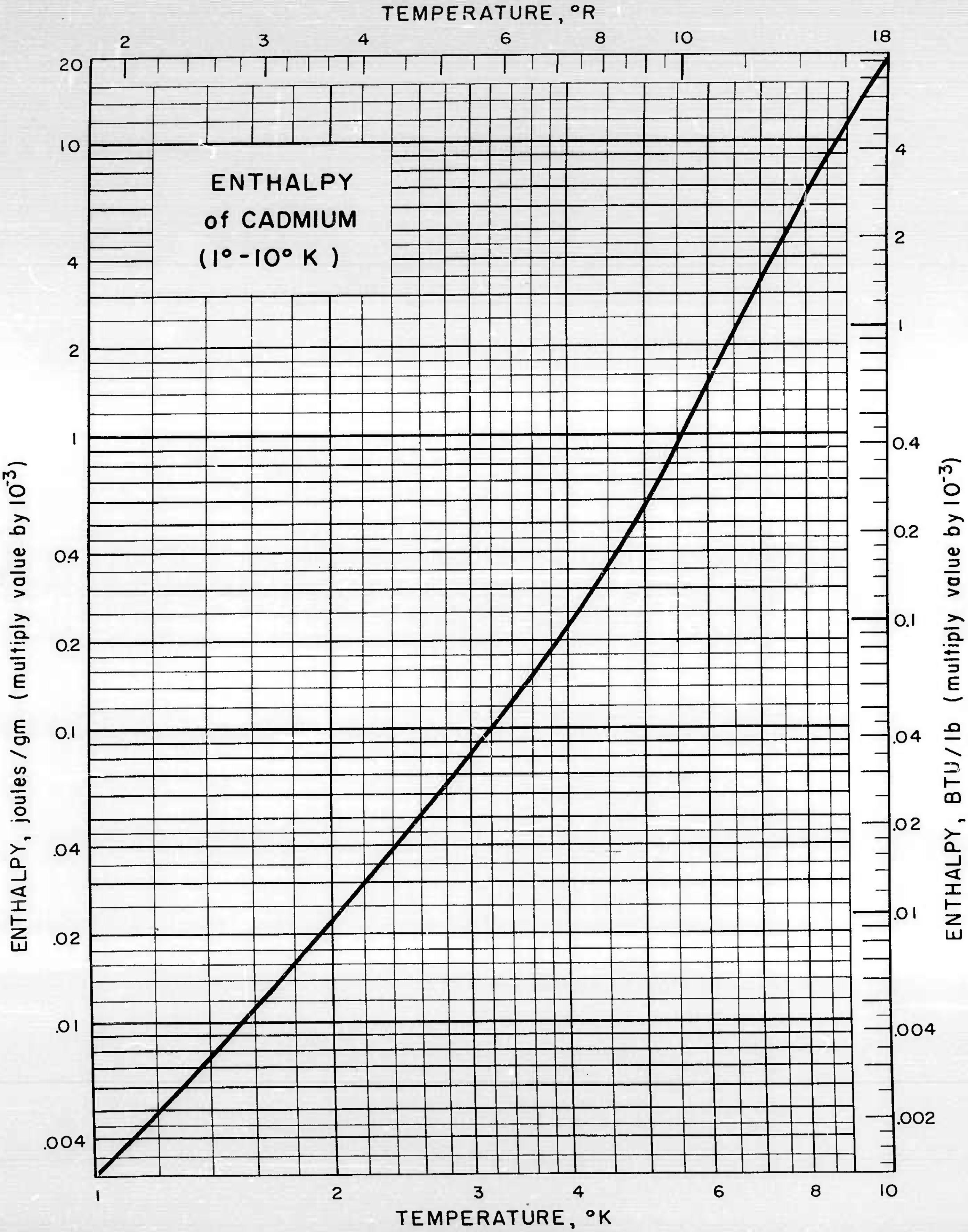
Table of Selected Values

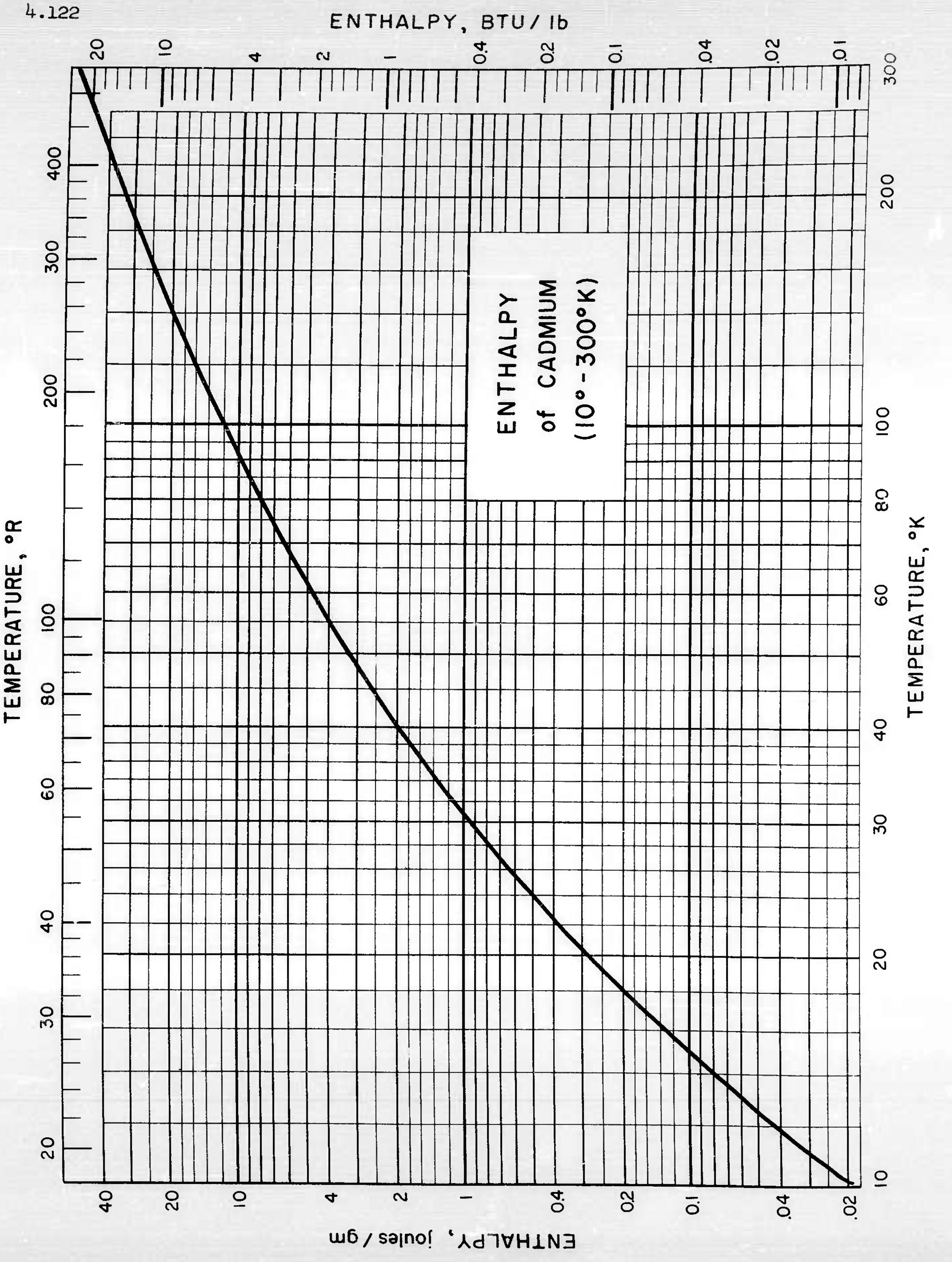
Temp. °K	C_p j/gm-°K	H j/gm	Temp. °K	C_p j/gm-°K	H j/gm
1	$.008 \times 10^{-3}$	$.003 \times 10^{-3}$	70	.172	6.43
2	.033 "	.022 "	80	.182	8.20
3	.090 "	.082 "	90	.190	10.1
4	.21 "	.22 "	100	.196	12.0
6	1.30 "	1.5 "	120	.205	16.0
8	4.30 "	7.0 "	140	.211	20.2
10	8.0 "	19.0 "	160	.215	24.4
15	.025	.102	180	.219	28.8
20	.046	.28	200	.222	33.2
25	.066	.56	220	.224	37.6
30	.086	.94	240	.226	42.1
40	.117	1.96	260	.228	46.7
50	.141	3.26	280	.229	51.2
60	.159	4.76	300	.230	55.8

RJC/JJG Issued: 10-18-59
Revised: 5-20-60


TEMPERATURE, °R
2
3
4
6
8
10
18
SPECIFIC HEAT of CADMIUM (1° - 10° K)
SPECIFIC HEAT (C_P), joules/gm °K (multiply value by 10^{-3})
8
6
4
2
1
0.8
0.6
0.4
0.2
0.1
.08
.06
.04
.02
.01
.008
SPECIFIC HEAT (C_P), BTU / lb °R (multiply value by 10^{-3})
1
0.8
0.6
0.4
0.2
0.1
.08
.06
.04
.02
.01
.008
.006
.004
.002
1
2
3
4
6
8
10
TEMPERATURE, °K


SPECIFIC HEAT (Cp), BTU/lb°R
.04
.02
.01
.008
.006
.004
.002
SPECIFIC HEAT
of CADMIUM
(10°-300°K)
TEMPERATURE, °R
400
300
200
100
80
60
40
30
20
TEMPERATURE, °K
300
200
100
80
60
40
30
20
10
SPECIFIC HEAT (Cp), joules/gm°K
0.2
0.1
.08
.06
.04
.02
.01
.008


TEMPERATURE, °R
2
3
4
6
8
10
18
ENTHALPY
of CADMIUM
(1° - 10° K)
20
10
4
2
1
0.4
0.2
0.1
.04
.02
.01
.004
4
2
1
0.4
0.2
0.1
.04
.02
.01
.004
.002
ENTHALPY, joules/gm (multiply value by 10^{-3})
ENTHALPY, BTU/lb (multiply value by 10^{-3})
1
2
3
4
6
8
10
TEMPERATURE, °K


ENTHALPY, BTU/ lb
20
10
4
2
1
0.4
0.2
0.1
.04
.02
.01
ENTHALPY
of CADMIUM
(10° - 300°K)
TEMPERATURE, °R
400
300
200
100
80
60
40
30
20
TEMPERATURE, °K
300
200
100
80
60
40
30
20
10
ENTHALPY, joules / gm
40
20
10
4
2
1
0.4
0.2
0.1
.04
.02

SPECIFIC HEAT, ENTHALPY of MERCURY

Sources of Data:

Busey, R. H. and Giauque, W. F., J. Am. Chem. Soc. 75, 806-9 (1953)

Misener, A. D., Proc. Roy. Soc. (London) A174, 262 (1940)

Smith, P. L. and Wolcott, N. M., Phil. Mag. 1, 854-65 (1956)

Other References:

Barchall, H., Z. Elektrochem. 17, 341 (1911)

Carpenter, L. G. and Stoodley, L. G., Phil. Mag. (7) 10, 249-65 (1930)

Koref, F., Ann. Physik 36, 49 (1911)

Maxwell, E. and Lutes, O. S., Phys. Rev. 95, 333-8 (1954)

Onnes, H. K. and Holst, G., Communs. Phys. Lab. Univ. Leiden No. 142c (1914)

Pickard, G. L. and Simon, F., Proc. Phys. Soc. 61, 1-9 (1948)

Pollitzer, F., Z. Elektrochem. 17, 5 (1911); Z. Elektrochem. 19, 513-18 (1913)

Russel, A. S., Physik. Z. 13, 59 (1912)

Simon, F., Ann. Physik 68, 241 (1922); Z. physik. Chem. 107, 279 (1923)

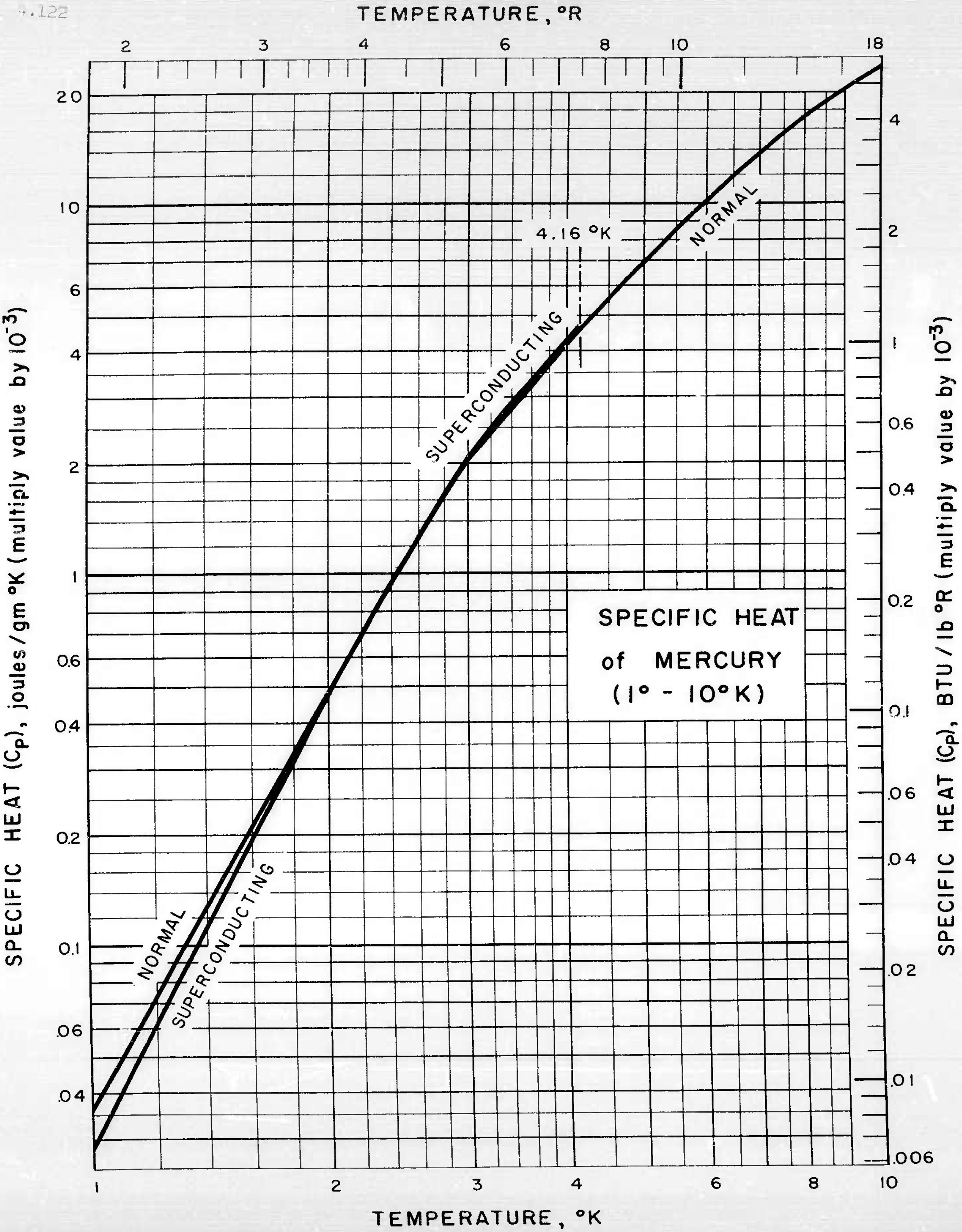
Table of Selected Values

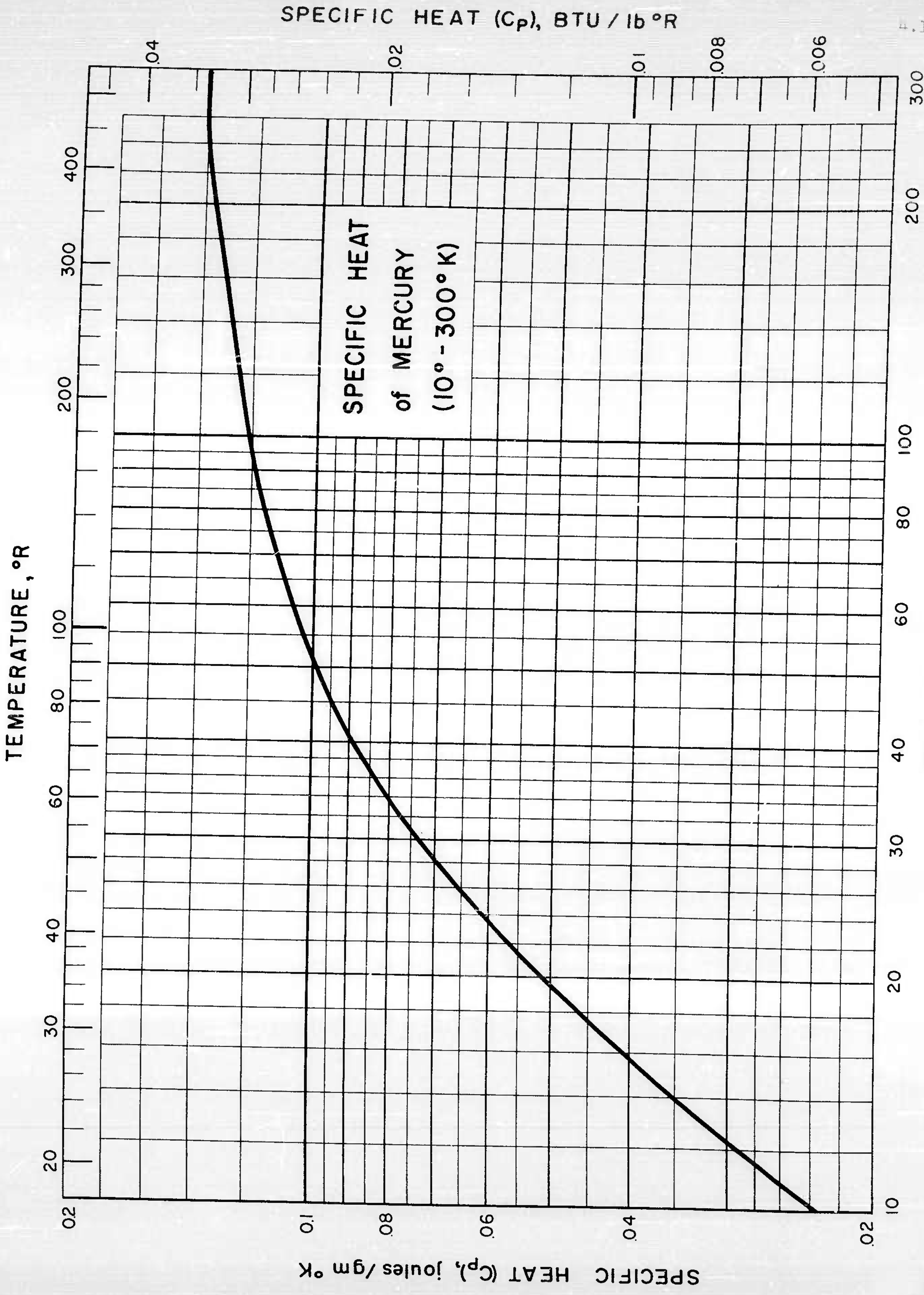
Temp. °K	C_p, j/gm-°K normal	C_p, j/gm-°K super-conducting	H, j/gm normal	H, j/gm super-conducting
1	0.000 036	0.000 029	0.000 0125	0.000 0042
2	.000 480	.000 480	.000 184	.000 175
3	.002 07	.002 09	.001 37	.001 38
4	.004 09	.004 17	.004 38	.004 45
4.16	.004 63	.004 71	.005 07	.005 16
6	.010 9		.019 4	
8	.017 5		.047 7	
10	.023 5		.088 6	
15	.038 0		.243	
20	.051 5		.468	
25	.063 3		.756	
30	.073 7		1.10	
40	.089 5		1.92	
50	.099 3		2.87	
60	.107		3.90	

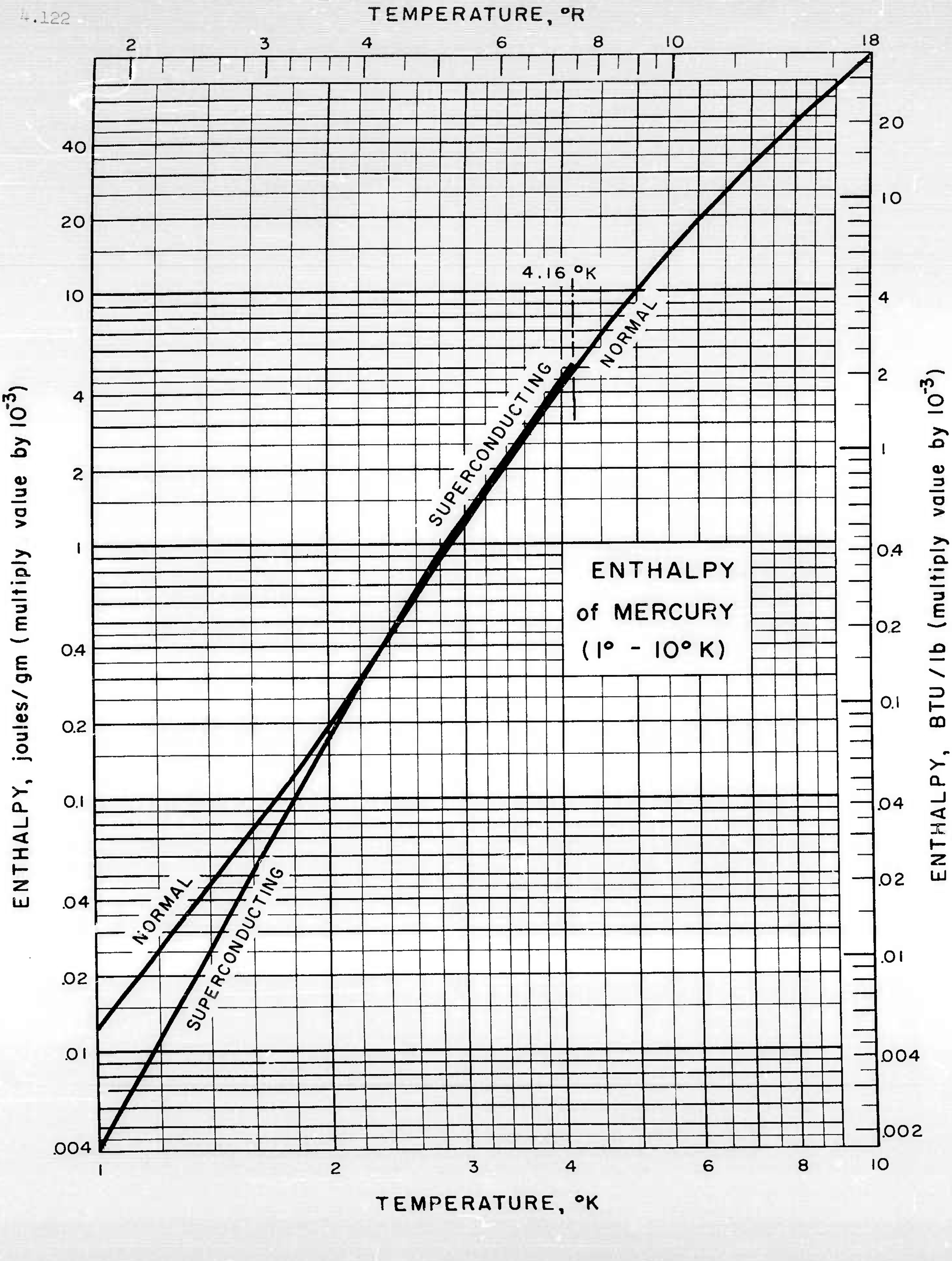
Temp. °K		C_p j/gm-°K	H j/gm
70		0.112	4.99
80		.116	6.13
90		.118	7.30
100		.121	8.50
120		.125	11.0
140		.128	13.5
160		.130	16.1
180		.133	18.7
200		.136	21.4
220		.139	24.1
234.3*	S	.142	26.1
234.3*	L	.142	37.6
240		.142	38.4
260		.141	41.2
280		.140	44.0
300		.139	46.8

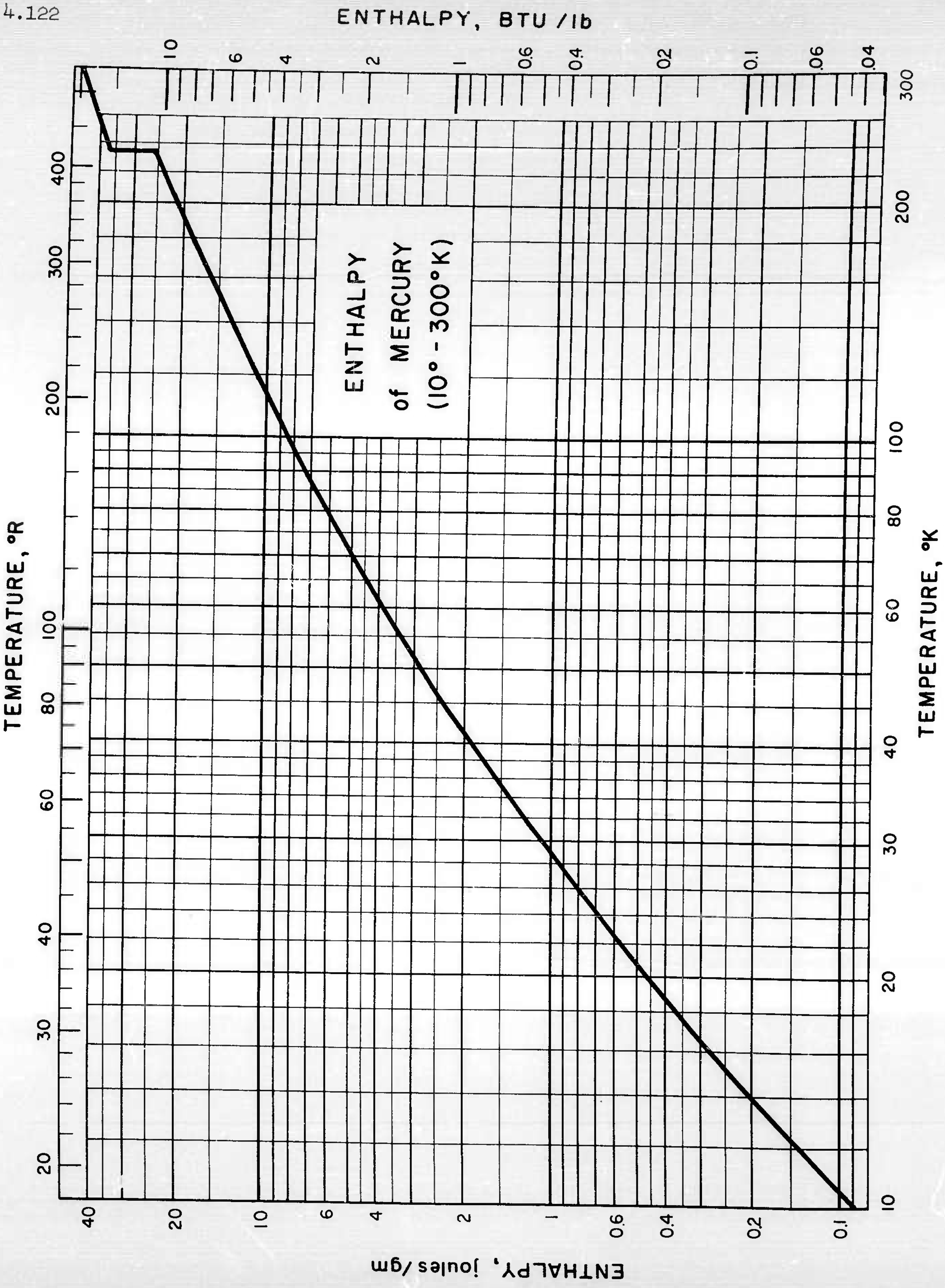
* Melting Temperature

RJC/JJG Issued: 12-18-59


TEMPERATURE, °R
2
3
4
6
8
10
18
20
10
6
4
2
1
0.6
0.4
0.2
0.1
.06
.04
4
2
1
0.6
0.4
0.2
0.1
.06
.04
.02
.01
.006
4.16 °K
NORMAL
SUPERCONDUCTING
NORMAL
SUPERCONDUCTING
SPECIFIC HEAT
of MERCURY
(1° - 10°K)
SPECIFIC HEAT (C_p), joules/gm °K (multiply value by 10^{-3})
SPECIFIC HEAT (C_p), BTU/lb °R (multiply value by 10^{-3})
1
2
3
4
6
8
10
TEMPERATURE, °K


SPECIFIC HEAT (Cp), BTU / lb °R
.4
.2
.01
.008
.006
SPECIFIC HEAT of MERCURY (10° - 300° K)
TEMPERATURE, °R
400
300
200
100
80
60
40
30
20
TEMPERATURE, °K
300
200
100
80
60
40
30
20
10
0.2
0.1
.08
.06
.04
.02
SPECIFIC HEAT (Cp), joules/gm °K


TEMPERATURE, °R
2
3
4
6
8
10
18
40
20
10
4
2
1
0.4
0.2
0.1
.04
.02
.01
.004
20
10
4
2
1
0.4
0.2
0.1
.04
.02
.01
.004
.002
4.16 °K
NORMAL
SUPERCONDUCTING
ENTHALPY, joules/gm (multiply value by 10^{-3})
ENTHALPY, BTU/lb (multiply value by 10^{-3})
ENTHALPY
of MERCURY
(1° - 10° K)
1
2
3
4
6
8
10
TEMPERATURE, °K


ENTHALPY, BTU /lb
ENTHALPY
of MERCURY
(10° - 300°K)
TEMPERATURE, °R
TEMPERATURE, °K
ENTHALPY, joules/gm

SPECIFIC HEAT, ENTHALPY of ZINC

Sources of Data:

Bronson, H. L. and Wilson, A. J. C., Can. J. Research A14, 181 (1936)
Clusius, K. and Harteck, P., Z. physik. Chem. 134, 243 (1928)
Silvidi, A. A. and Daunt, J. G., Phys. Rev. (2) 77, 125 (1950)
Smith, P. L., Phil. Mag. 46, 744 (1955)

Other References:

Eucken, A. and Schwers, F., Verhandl. deut. physik. Ges. 15, 578 (1913)
Ewald, R., Ann. Physik. (4) 44, 1213 (1914)
Griffiths, E. G. and Griffiths, E., Phil. Trans. Roy. Soc. London A214, 319 (1914); Proc. Roy. Soc. (London) A90, 557 (1914)
Keesom, W. H., Pontif. Acad. Sci. Novi Lyncaei, Sci. Nuncius Radiophonicus 10, 5 (1932)
Keesom, W. H. and Kok, J. A., Physica 1, 770 (1934); Proc. Acad. Sci. Amsterdam 37, 377 (1934)
Keesom, W. H. and Van Den Ende, J. N., Communs. Kamerlingh Onnes Lab. Univ. Leiden 219b, 10 (1932); Proc. Acad. Sci. Amsterdam 35, 143 (1932)
Koref, F., Ann. Physik. (4) 36, 49 (1911)
Nernst, W., Ann. Physik (4) 36, 395 (1911); Sitzber. kgl. preuss. Akad. Wiss. 306 (1911)
Pollitzer, F., Z. Elektrochem. 17, 15 (1911)
Richards, T. W. and Jackson, F. G., Z. physik. Chem. 70, 414 (1910)
Schimpff, H., Z. physik. Chem. 71, 257 (1910)
Schmitz, H. E., Proc. Roy. Soc. (London) 72, 177 (1903)

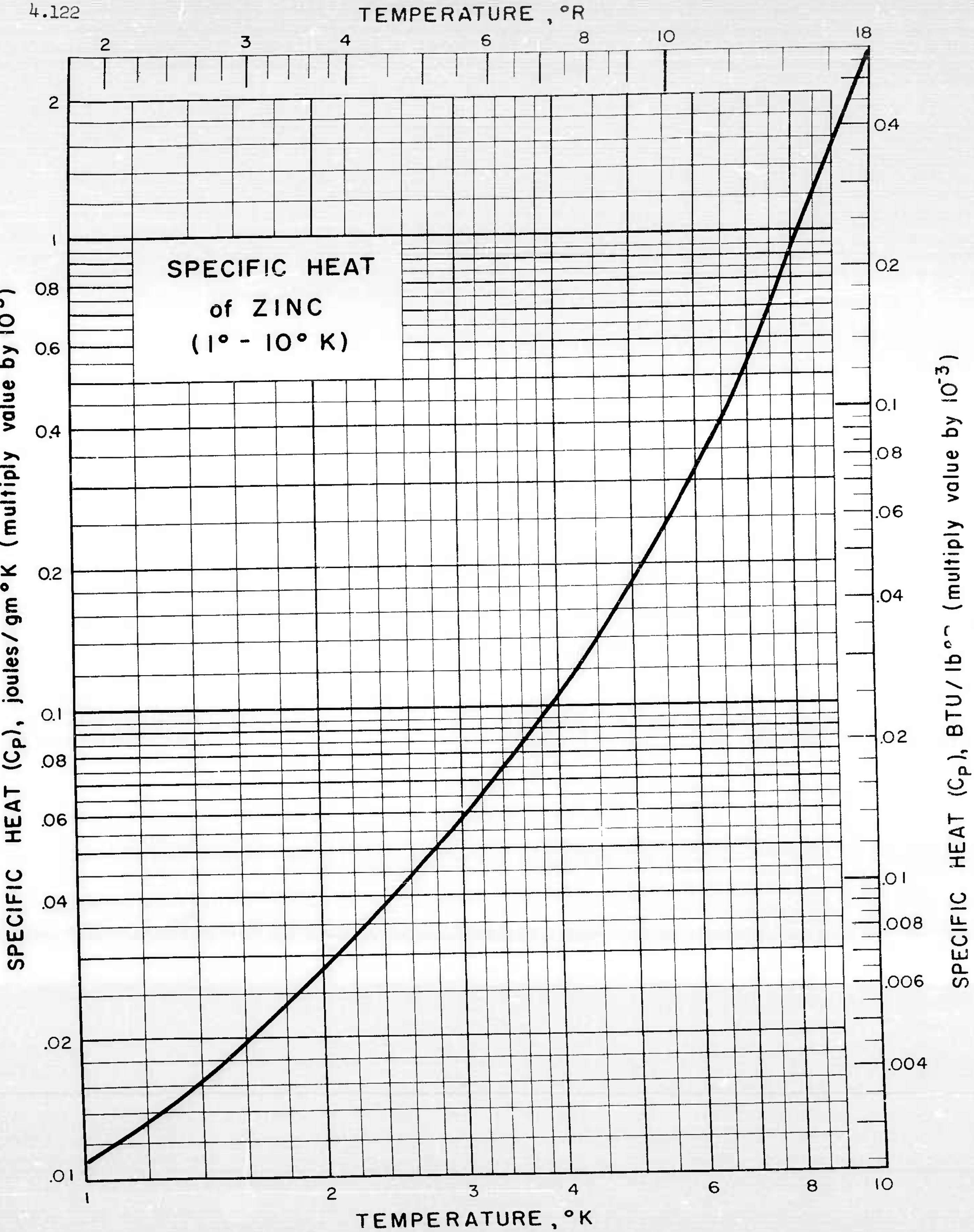
Comments:

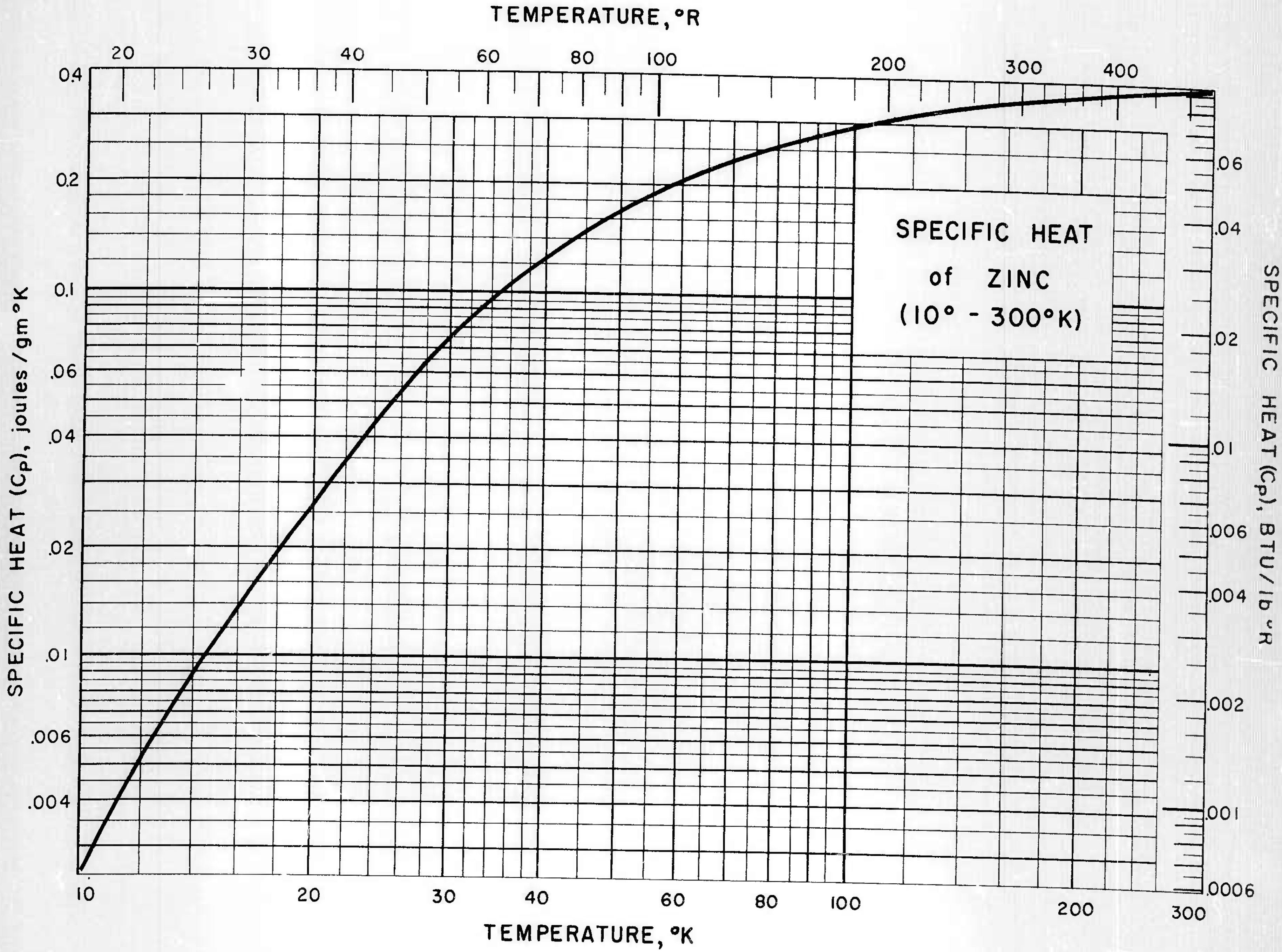
For $0 < T \leq 6°K$

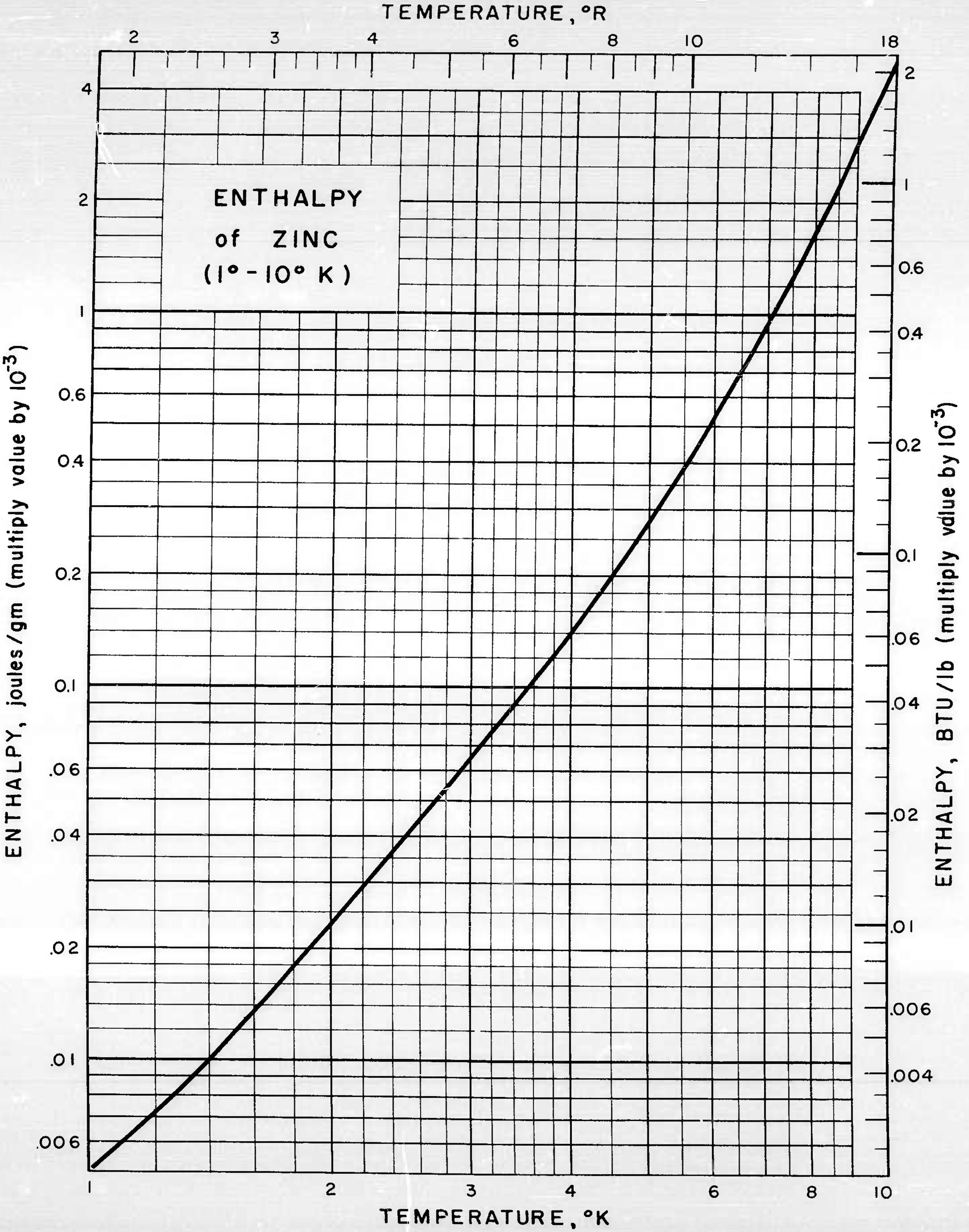
$$C_p = 29.7\,(T/304)^3 + 9.8 \times 10^{-6}\,T \text{ j/gm-°K}$$

Temp. °K	C_p j/gm-°K	H j/gm	Temp. °K	C_p j/gm-°K	H j/gm
1	.011 x 10^{-3}	.005 x 10^{-3}	70	.236	7.23
2	.028 "	.023 "	80	.258	9.70
3	.058 "	.065 "	90	.277	12.38
4	.11 "	.14 "	100	.293	15.24
6	.29 "	.53 "	120	.319	21.38
8	.96 "	1.6 "	140	.337	27.96
10	2.5 "	5.0 "	160	.350	34.85
15	.011	.034	180	.360	41.95
20	.026	.125	200	.367	49.22
25	.049	.31	220	.373	56.62
30	.076	.62	240	.378	64.12
40	.125	1.62	260	.382	71.71
50	.171	3.11	280	.386	79.39
60	.208	5.01	300	.390	87.15

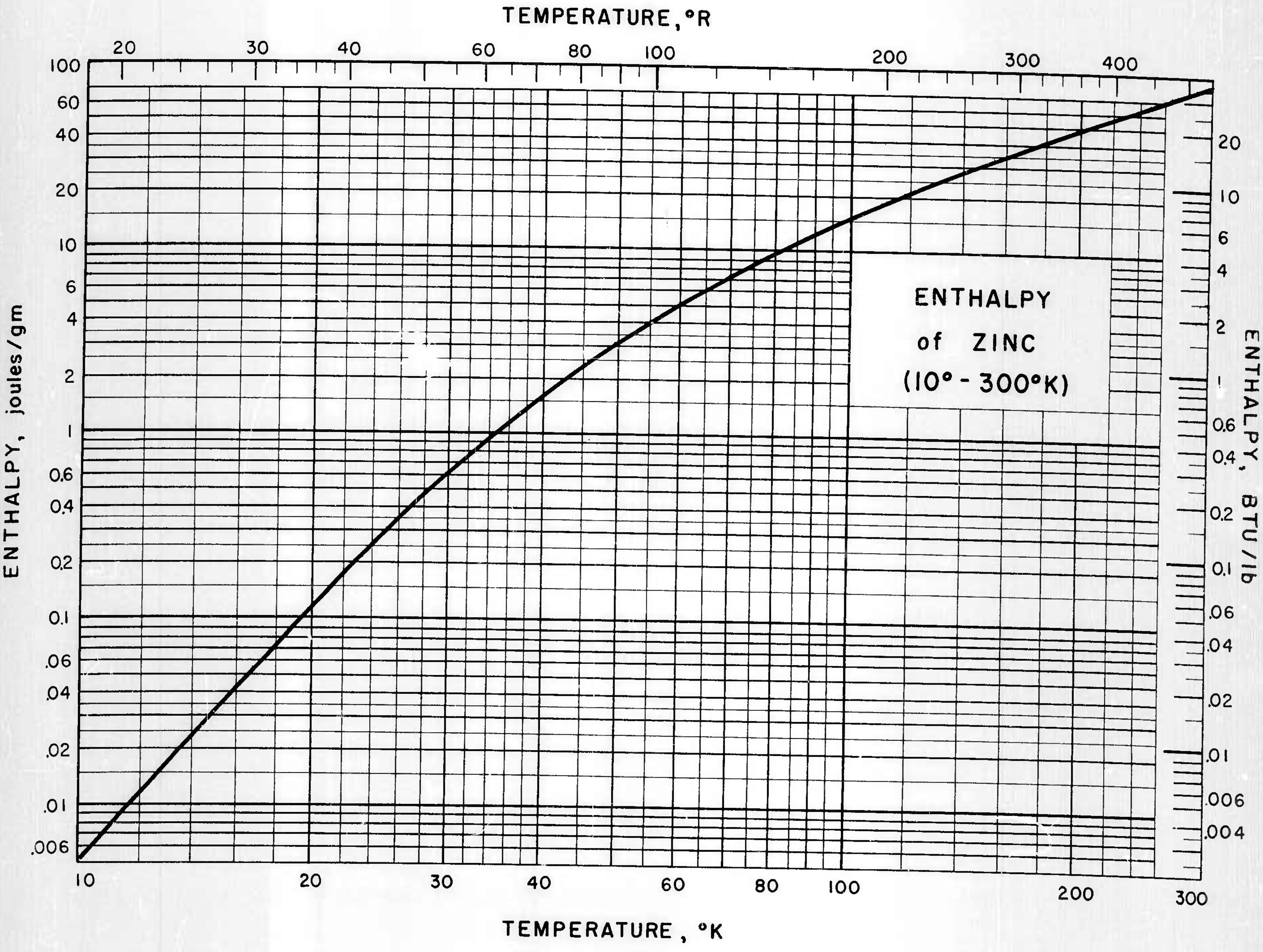
RJC/JJG Issued: 12-18-59
Revised: 5-20-60


TEMPERATURE , °R
2
3
4
6
8
10
18
SPECIFIC HEAT
of ZINC
(1° - 10° K)
SPECIFIC HEAT (C_p), joules/gm °K (multiply value by 10^{-3})
2
1
0.8
0.6
0.4
0.2
0.1
.08
.06
.04
.02
.01
SPECIFIC HEAT (C_p), BTU/lb °R (multiply value by 10^{-3})
0.4
0.2
0.1
.08
.06
.04
.02
.01
.008
.006
.004
1
2
3
4
6
8
10
TEMPERATURE , °K


TEMPERATURE, °R
20
30
40
60
80
100
200
300
400
SPECIFIC HEAT
of ZINC
(10° - 300°K)
SPECIFIC HEAT (C_p), joules/gm °K
0.4
0.2
0.1
.06
.04
.02
.01
.006
.004
SPECIFIC HEAT (C_p), BTU/lb °R
.06
.04
.02
.01
.006
.004
.002
.001
.0006
TEMPERATURE, °K
10
20
30
40
60
80
100
200
300



TEMPERATURE, °R
2
3
4
6
8
10
18
ENTHALPY
of ZINC
(1° - 10° K)
ENTHALPY, joules/gm (multiply value by 10^{-3})
4
2
1
0.6
0.4
0.2
0.1
.06
.04
.02
.01
.006
ENTHALPY, BTU/lb (multiply value by 10^{-3})
2
1
0.6
0.4
0.2
0.1
.06
.04
.02
.01
.006
.004
1
2
3
4
6
8
10
TEMPERATURE, °K


TEMPERATURE, °R
20
30
40
60
80
100
200
300
400
ENTHALPY, joules/gm
100
60
40
20
10
6
4
2
1
0.6
0.4
0.2
0.1
.06
.04
.02
.01
.006
ENTHALPY, BTU/lb
20
10
6
4
2
1
0.6
0.4
0.2
0.1
.06
.04
.02
.01
.006
.004
ENTHALPY
of ZINC
(10° - 300°K)
10
20
30
40
60
80
100
200
300
TEMPERATURE, °K

SPECIFIC HEAT, ENTHALPY of ALUMINUM

Sources of Data:

Giauque, W. F. and Meads, P. F., J. Am. Chem. Soc. 63, 1897-1901 (1941)
Maier, C. G. and Anderson, C. T., J. Chem. Phys. 2, 513-27 (1934)
Phillips, N. E., Low Temperature Physics and Chemistry, Univ. Wisconsin Press (1958)

Other References:

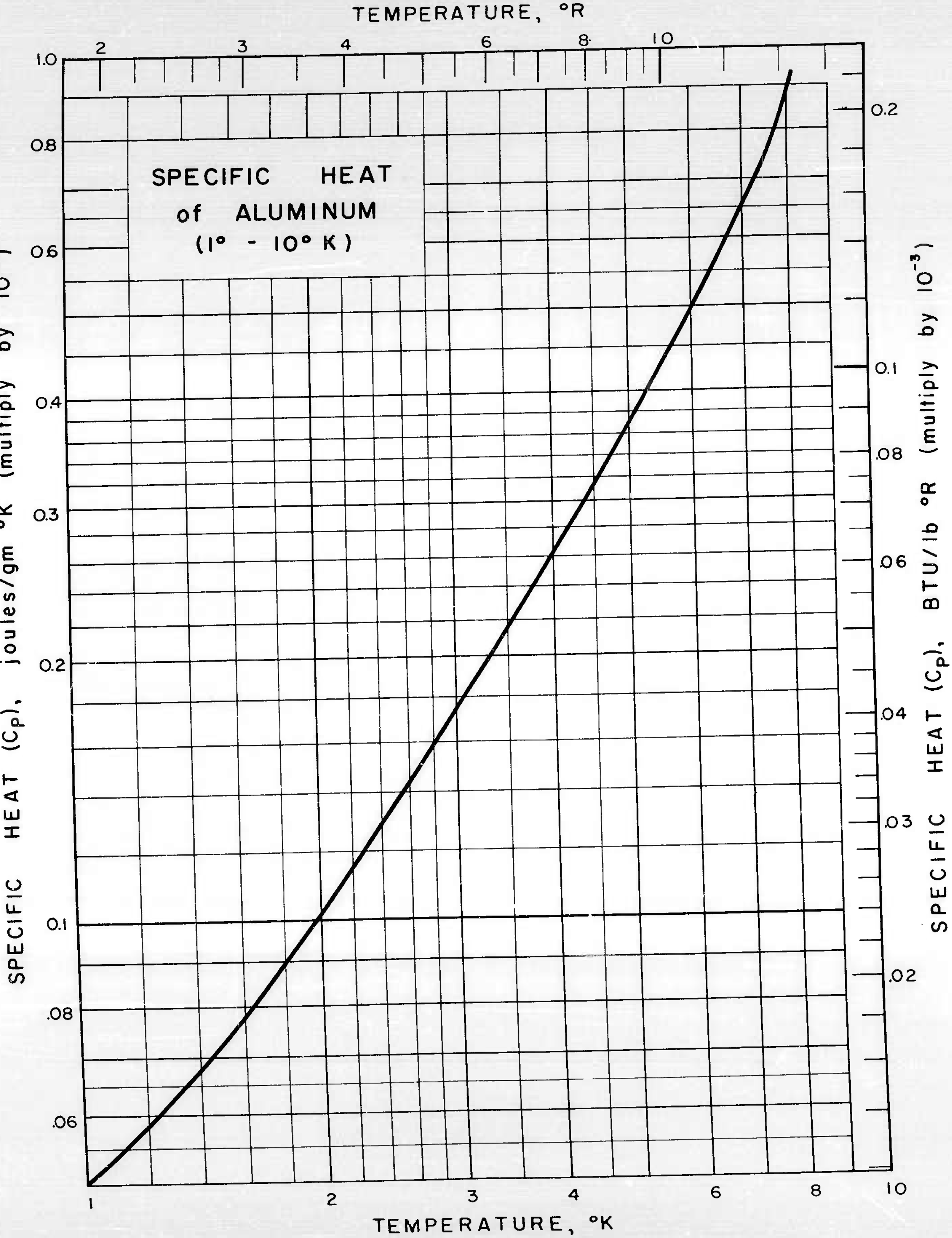
Behn, U., Ann. Physik Beiblätter 25, 178 (1901)
Goodman, B. B., Compt. rend. 244, 2899 (1957)
Griffiths, E. G. and Griffiths, E., Phil. Trans. Roy. Soc. London A90, 557 (1914)
Kok, J. A. and Keesom, W. H., Physica 4, 835 (1937)
Koref, F., Ann. Physik (4) 36, 49 (1911)
Nernst, W., Ann. Physik (4) 36, 395 (1911)
Nernst, W. and Lindemann, F. A., Z. Elektrochem. 17, 817 (1911)
Nernst, W. and Schwers, F., Sitzber. kgl. preuss. Akad. Wiss. 355 (1914)
Richards, T. W. and Jackson, F. G., Z. physik. Chem. 70, 414 (1910)
Schmitz, H. E., Proc. Roy. Soc. (London) 72, 177 (1903)
Tilden, W. A., Proc. Roy. Soc. (London) 71, 220 (1903)

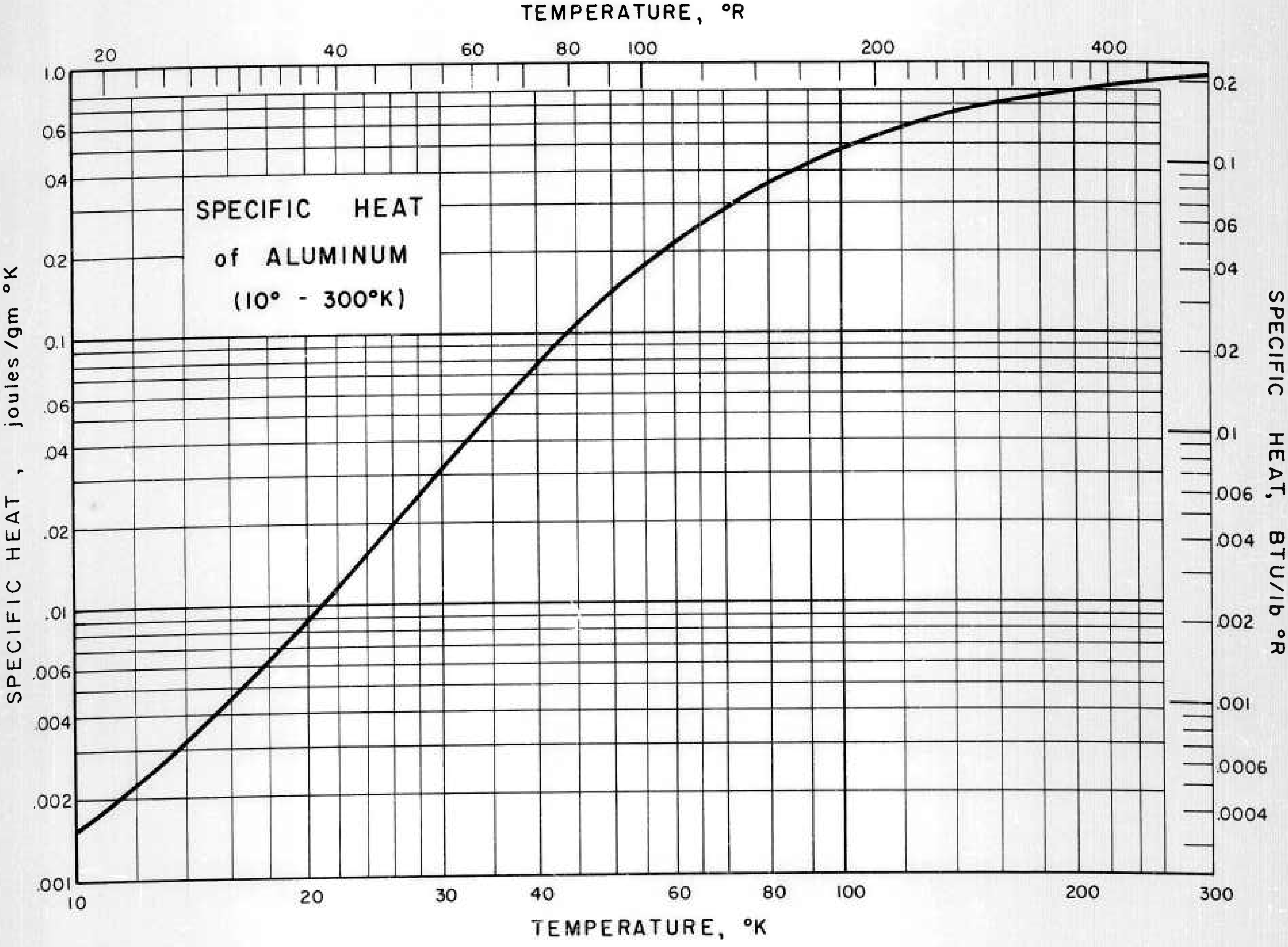
Table of Selected Values

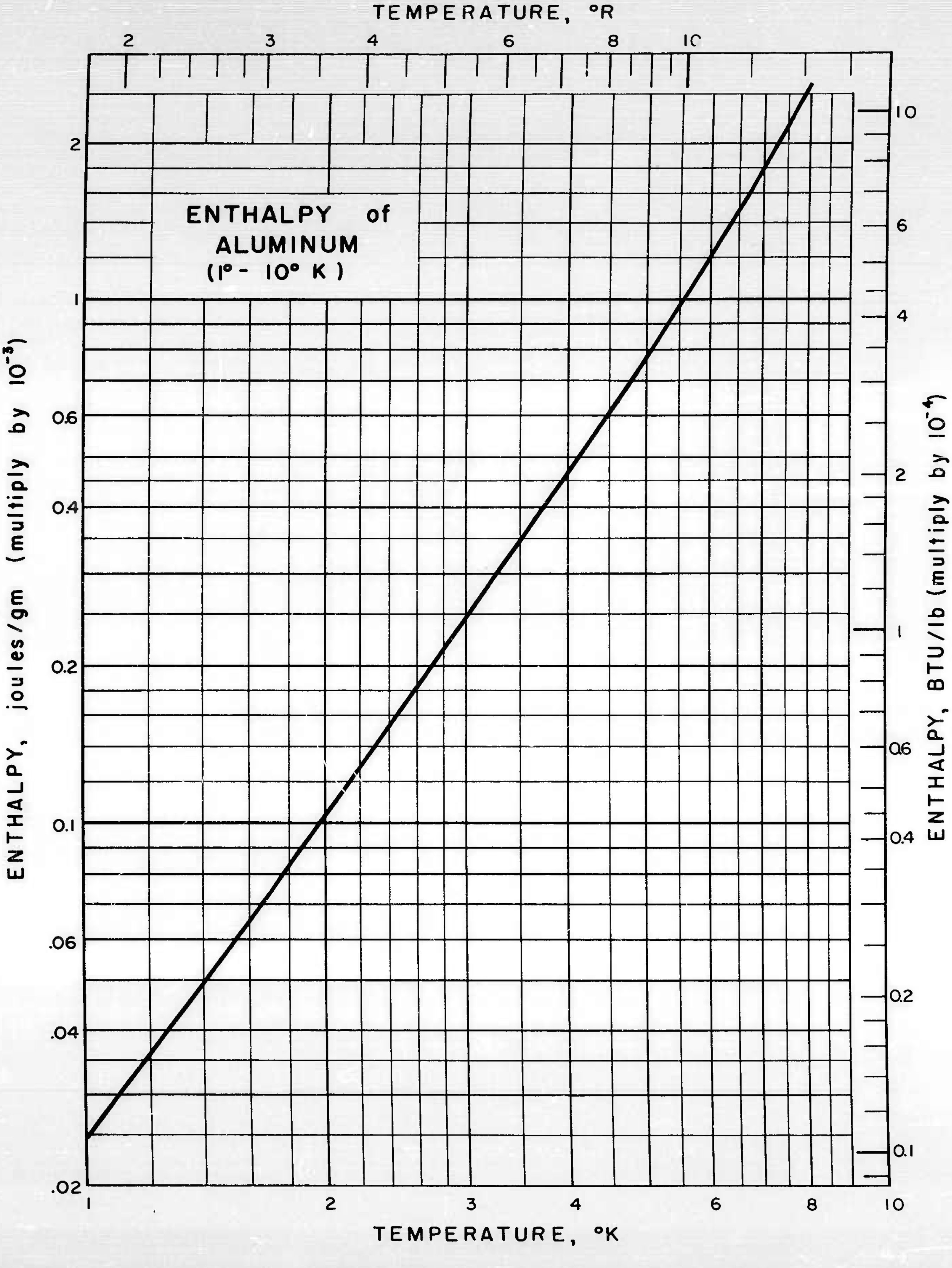
Temp. °K	C_p j/gm-°K	H j/gm	Temp. °K	C_p j/gm-°K	H j/gm
1	0.000 10*		60	0.214	3.64
1	.000 051	0.000 025	70	.287	6.15
2	.000 108	.000 105	80	.357	9.37
3	.000 176	.000 246	90	.422	13.25
4	.000 261	.000 463	100	.481	17.76
6	.000 50	.001 21	120	.580	28.4
8	.000 88	.002 6	140	.654	40.7
10	.001 4	.004 9	160	.713	54.4
15	.004 0	.018	180	.760	69.2
20	.008 9	.048	200	.797	84.8
25	.017 5	.112	220	.826	101.0
30	.031 5	.232	240	.849	117.8
35	.051 5	.436	260	.869	135.0
40	.077 5	.755	280	.886	152.5
50	.142	1.85	300	.902	170.4

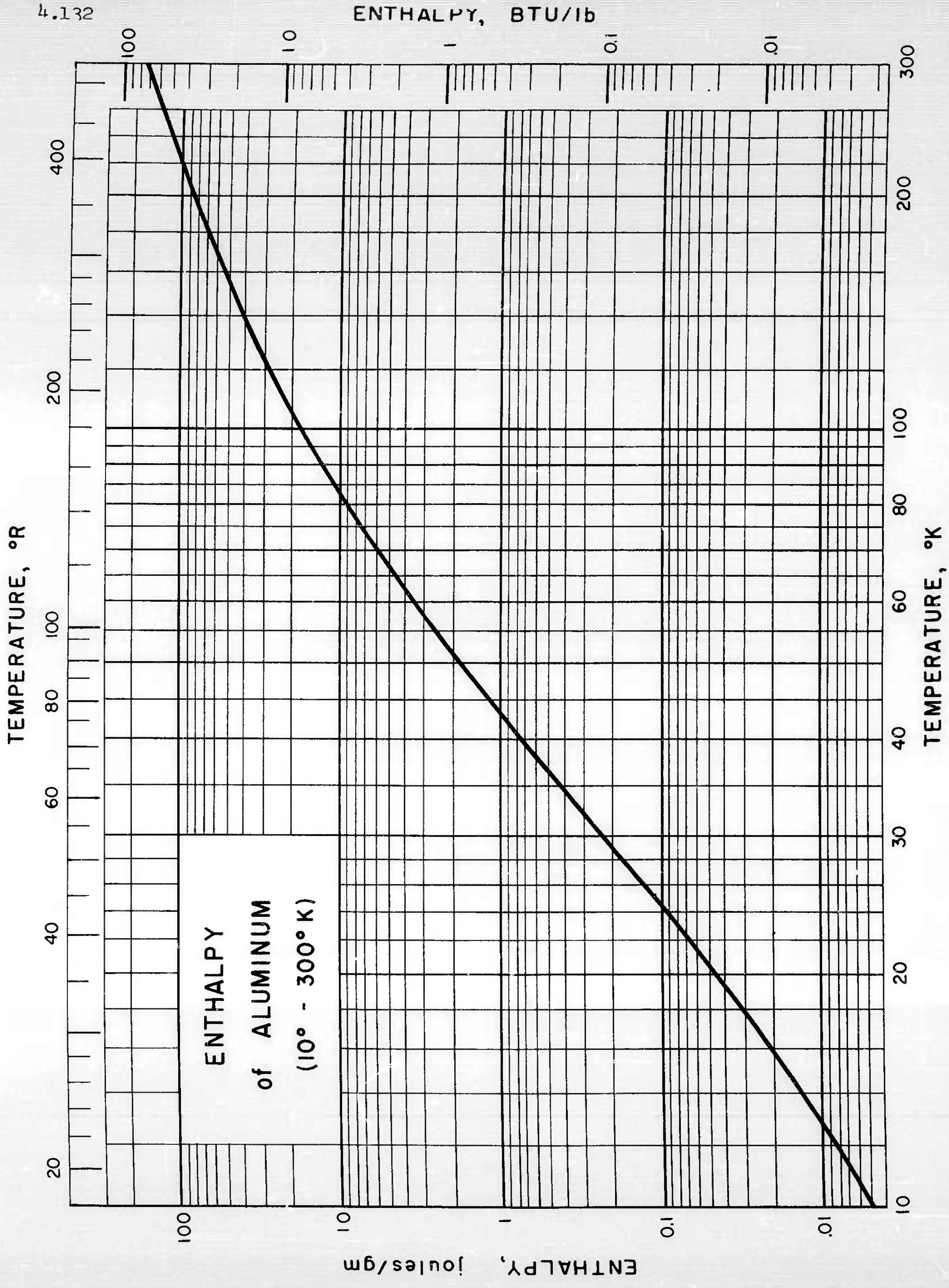
* Superconducting

RJC Issued: 6/15/59


TEMPERATURE, °R
2
3
4
6
8
10
1.0
0.8
0.6
0.4
0.3
0.2
0.1
.08
.06
SPECIFIC HEAT
of ALUMINUM
(1° - 10° K)
SPECIFIC HEAT (C_p), joules/gm °K (multiply by 10^{-3})
0.2
0.1
.08
.06
.04
.03
.02
SPECIFIC HEAT (C_p), BTU/lb °R (multiply by 10^{-3})
1
2
3
4
6
8
10
TEMPERATURE, °K


SPECIFIC HEAT
of ALUMINUM
(10° - 300°K)
TEMPERATURE, °R
20
40
60
80
100
200
400
TEMPERATURE, °K
10
20
30
40
60
80
100
200
300
SPECIFIC HEAT, joules/gm °K
1.0
0.6
0.4
0.2
0.1
.06
.04
.02
.01
.006
.004
.002
.001
SPECIFIC HEAT, BTU/lb °R
0.2
0.1
.06
.04
.02
.01
.006
.004
.002
.001
.0006
.0004


TEMPERATURE, °R
2
3
4
6
8
10
ENTHALPY of
ALUMINUM
(1° - 10° K)
ENTHALPY, joules/gm (multiply by 10^{-3})
2
1
0.6
0.4
0.2
0.1
.06
.04
.02
ENTHALPY, BTU/lb (multiply by 10^{-4})
10
6
4
2
1
0.6
0.4
0.2
0.1
1
2
3
4
6
8
10
TEMPERATURE, °K


ENTHALPY, BTU/lb
100
10
1
0.1
.01
TEMPERATURE, °R
400
200
100
80
60
40
20
TEMPERATURE, °K
300
200
100
80
60
40
30
20
10
ENTHALPY
of ALUMINUM
(10° - 300° K)
ENTHALPY, joules/gm
100
10
1
0.1
.01

SPECIFIC HEAT and ENTHALPY of INDIUM

Sources of Data:

Clement, J. R. and Quinnell, E. H., Phys. Rev. 92, 258 (1953)

Clusius, K. and Schachinger, L., Z. Naturforsch. A7, 185 (1952)

Other References:

Clement, J. R. and Quinnell, E. H., Nat. Bur. Standards Circ. 519, 89 (1952) and Phys. Rev. 79, 1028 (1950)

Table of Selected Values

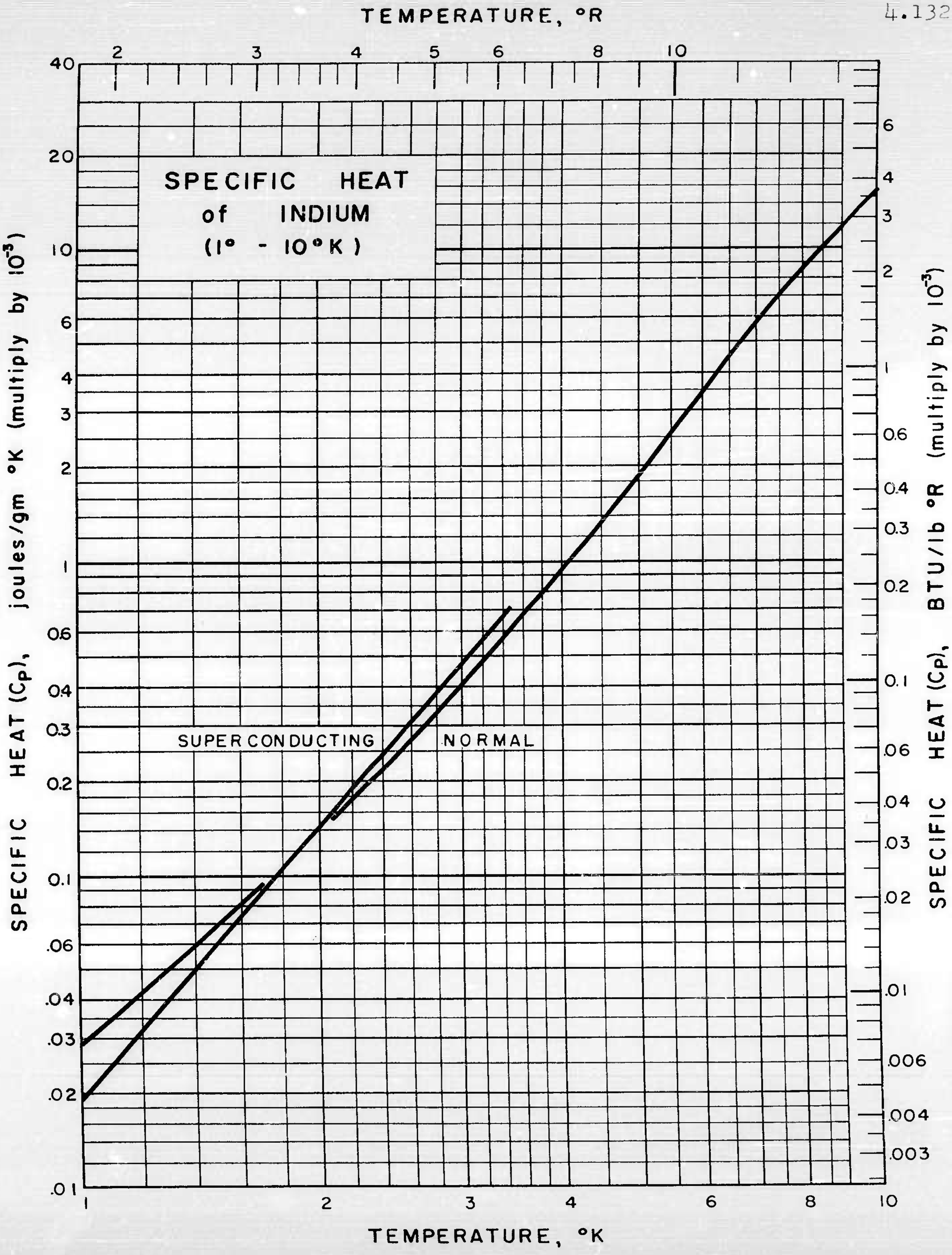
T °K	Cp j/gm-°K	H j/gm
1	0.000 029	0.000 011
1	.000 019*	.000 006*
2	.000 138	.000 085
2	.000 141*	.000 073*
3	.000 410	.000 341
3	.000 464*	.000 357*
3.40**	.000 584	.000 537
3.40	.000 669*	.000 581*
4	.000 95	.000 99
6	.003 59	.005 20
8	.008 55	.017 0
10	.015 5	.040 8
15	.036 7	.170
20	.060 8	.413
25	.085 7	.778
30	.108	1.265
40	.141	2.52
50	.162	4.04

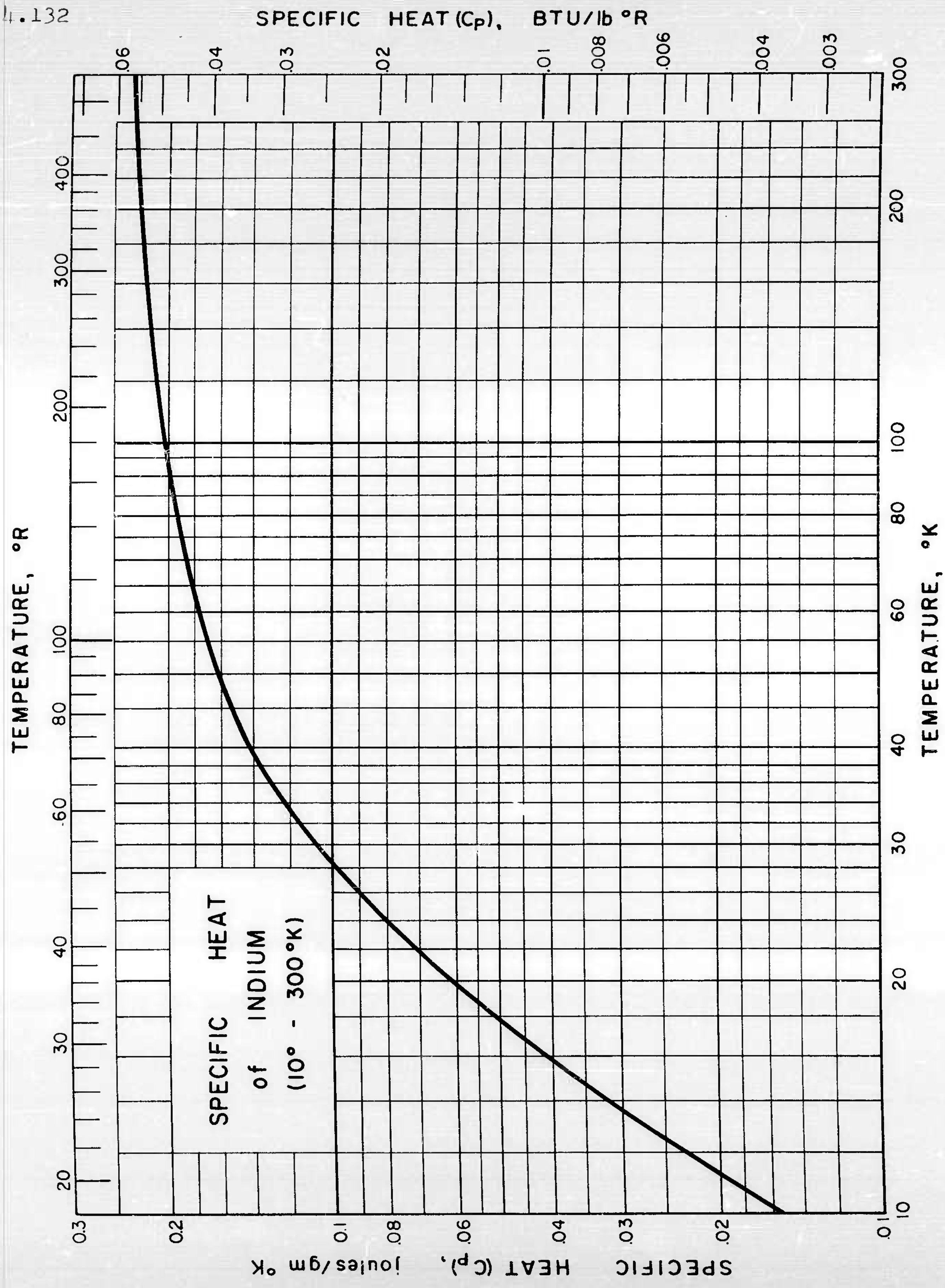
T °K	Cp j/gm-°K	H j/gm
60	0.176	5.73
70	.186	7.53
80	.193	9.42
90	.198	11.38
100	.203	13.39
120	.211	17.53
140	.217	21.81
160	.220	26.18
180	.223	30.61
200	.225	35.08
220	.227	39.59
240	.229	44.14
260	.230	48.72
280	.232	53.34
300	.233	58.0

* Superconducting

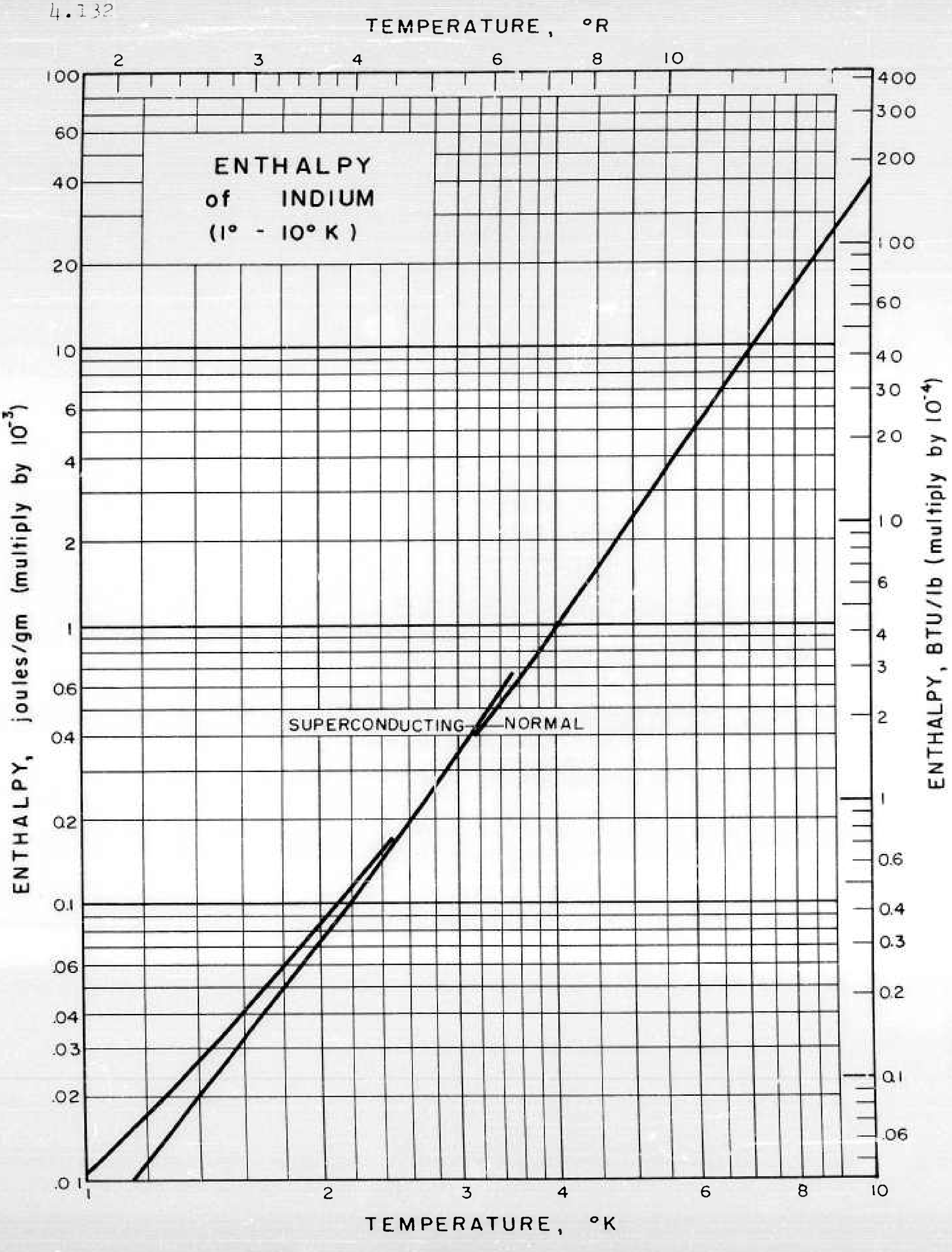
** Superconducting transition temperature

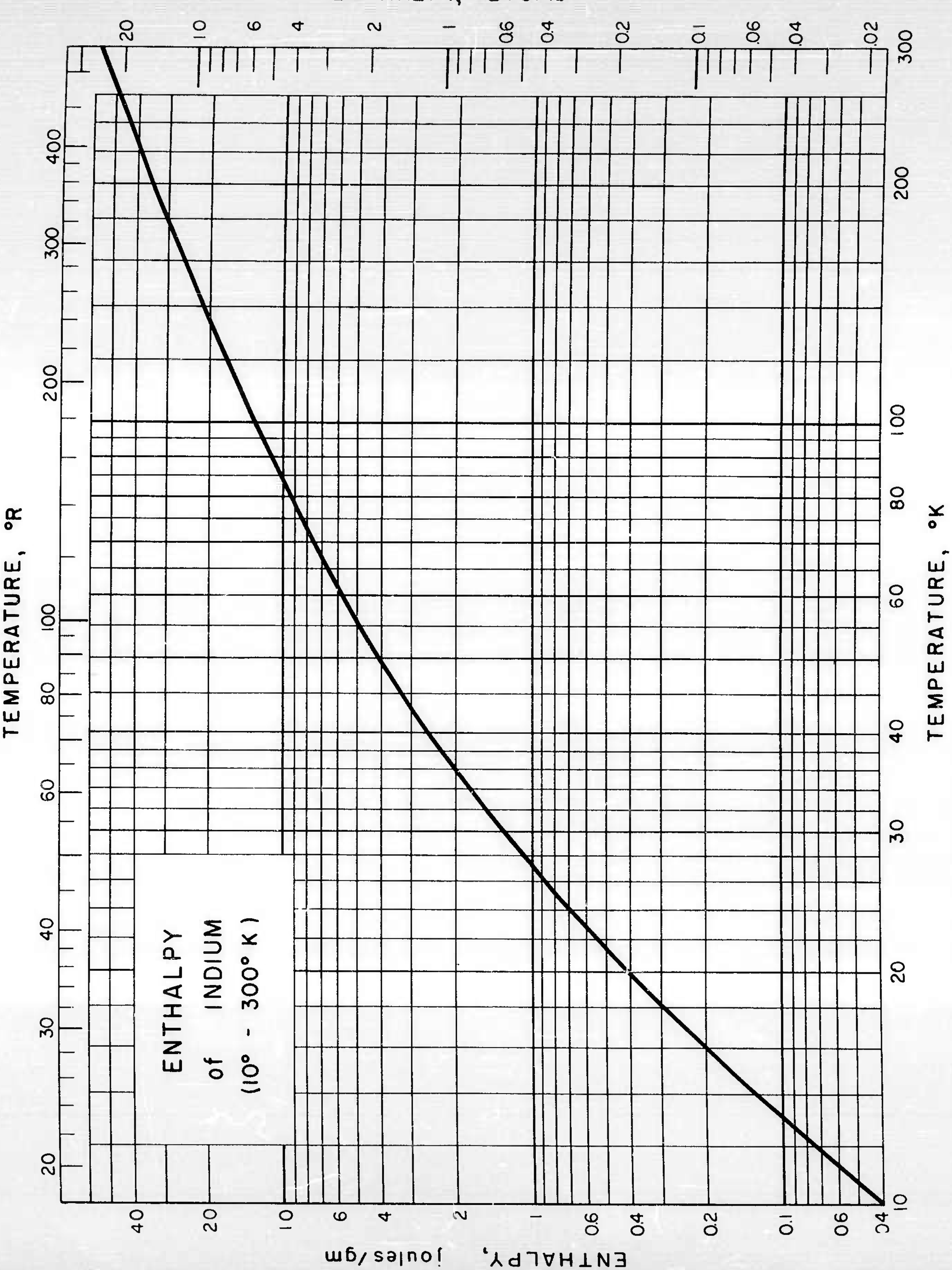
RJC Issued: 6-11-59
Revised: 5-20-60


TEMPERATURE, °R
SPECIFIC HEAT
of INDIUM
(1° - 10°K)
SUPERCONDUCTING
NORMAL
SPECIFIC HEAT (C_P), joules/gm °K (multiply by 10^{-3})
SPECIFIC HEAT (C_P), BTU/lb °R (multiply by 10^{-3})
TEMPERATURE, °K


SPECIFIC HEAT (Cp), BTU/lb °R
.06
.04
.03
.02
.01
.008
.006
.004
.003
SPECIFIC HEAT of INDIUM (10° - 300°K)
TEMPERATURE, °R
TEMPERATURE, °K
SPECIFIC HEAT (Cp), joules/gm °K
0.3
0.2
0.1
0.08
0.06
0.04
0.03
0.02
0.01

4.132


TEMPERATURE, °R
2
3
4
6
8
10
ENTHALPY
of INDIUM
(1° - 10° K)
SUPERCONDUCTING
NORMAL
ENTHALPY, joules/gm (multiply by 10^{-3})
100
60
40
20
10
6
4
2
1
0.6
0.4
0.2
0.1
.06
.04
.03
.02
.01
ENTHALPY, BTU/lb (multiply by 10^{-4})
400
300
200
100
60
40
30
20
10
6
4
3
2
1
0.6
0.4
0.3
0.2
0.1
.06
1
2
3
4
6
8
10
TEMPERATURE, °K


ENTHALPY, BTU/lb
20 10 6 4 2 1 0.6 0.4 0.2 0.1 0.06 0.04 0.02
TEMPERATURE, °R
400 300 200 100 80 60 40 30 20
TEMPERATURE, °K
300 200 100 80 60 40 30 20 10
ENTHALPY
of INDIUM
(10° - 300° K)
ENTHALPY, joules/gm
40 20 10 6 4 2 1 0.6 0.4 0.2 0.1 0.06 0.04

SPECIFIC HEAT, ENTHALPY of TITANIUM

Sources of Data:

Aven, M. H., Craig, R. S., Waite, T. R. and Wallace, W. E., Phys. Rev. 102, 1263 (1956)

Kothen, C. W. and Johnston, H. L., J. Am. Chem. Soc. 75, 3101 (1953)

Wolcott, N. M., Conf. de Physique des Basses Temperatures, Paris (1955)

Other References:

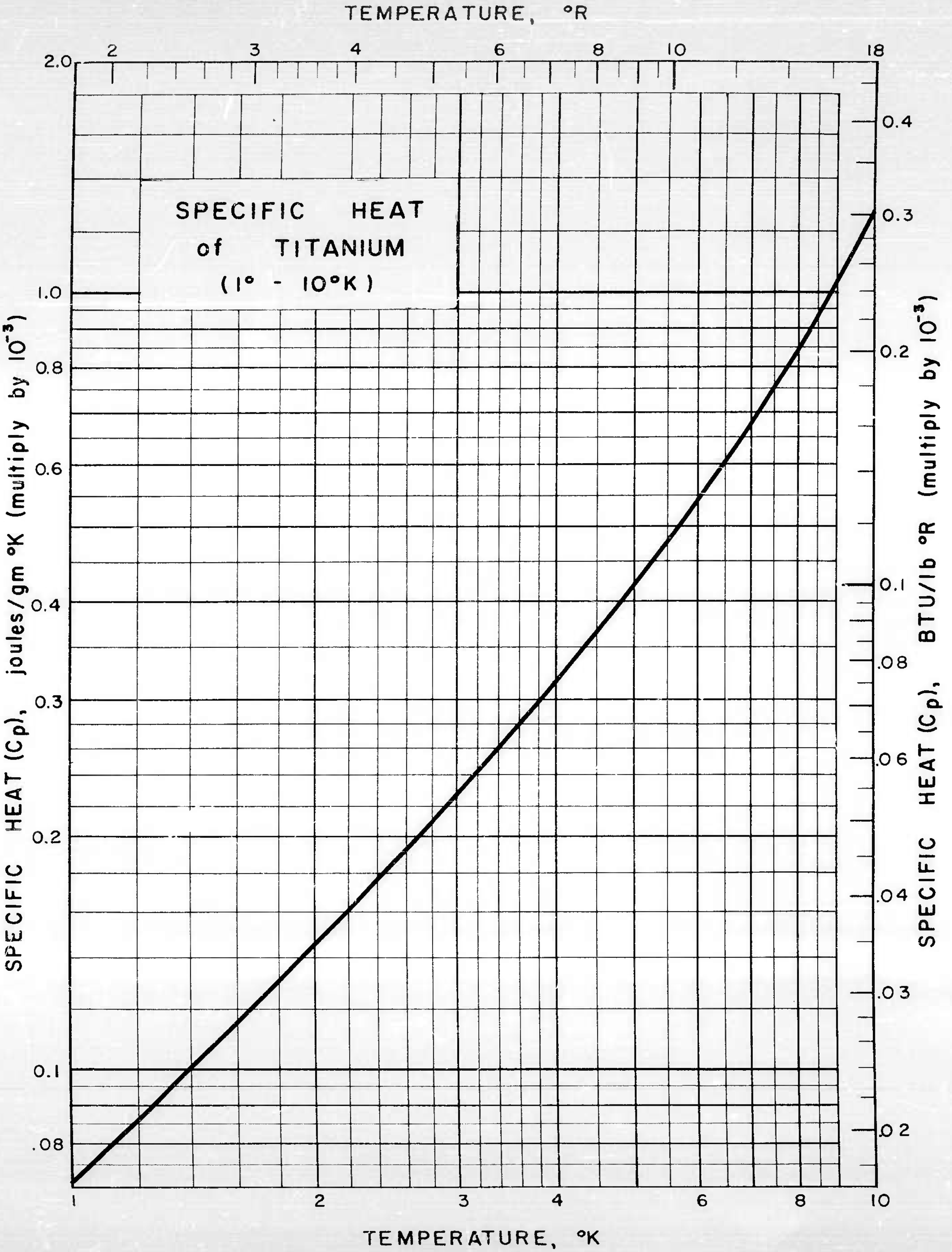
Estermann, I., Friedberg, S. A. and Goldman, J. E., Phys. Rev. 87, 582 (1952)

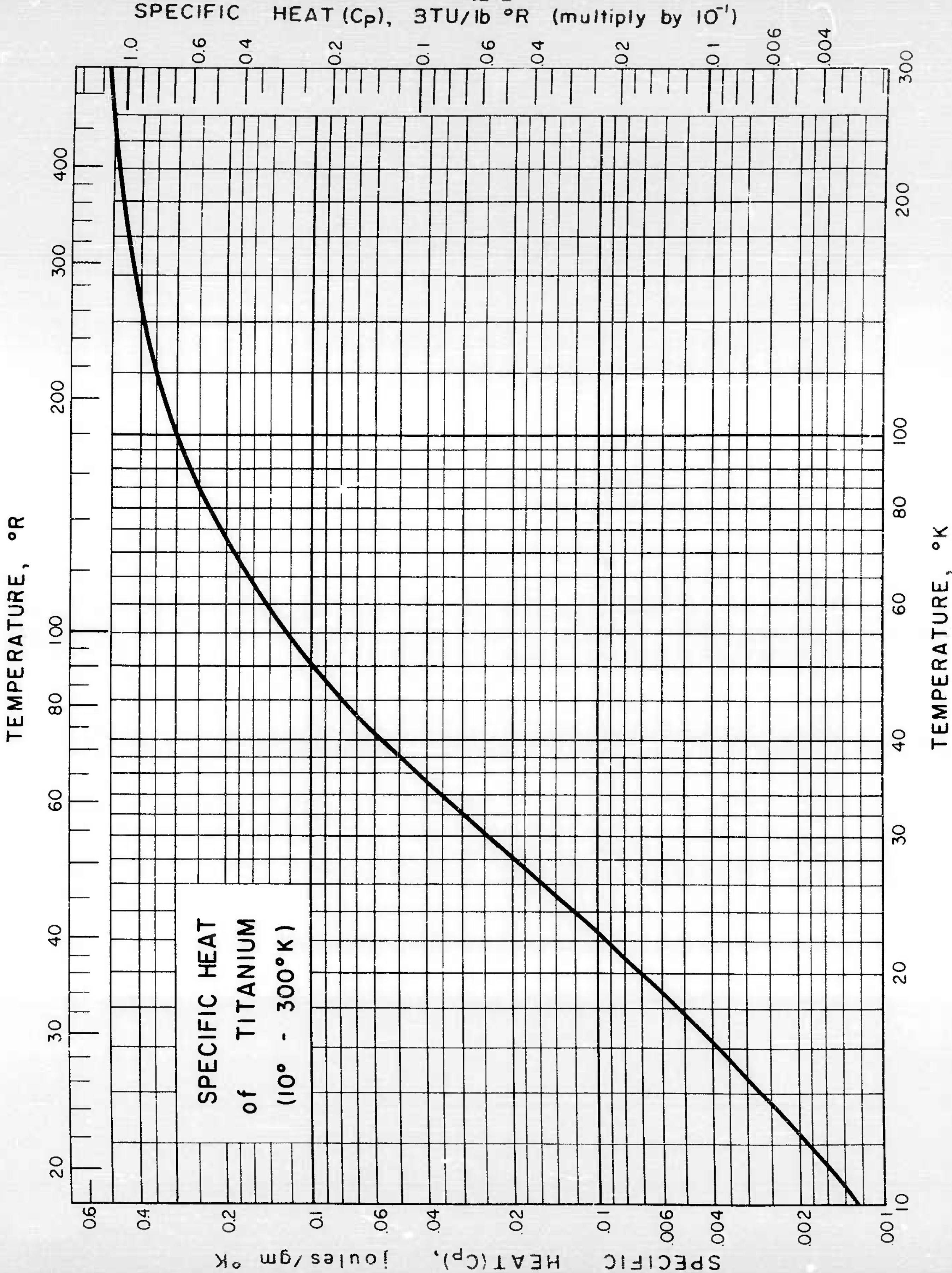
Kelley, K. K., Ind. Eng. Chem. 36, 865 (1944)

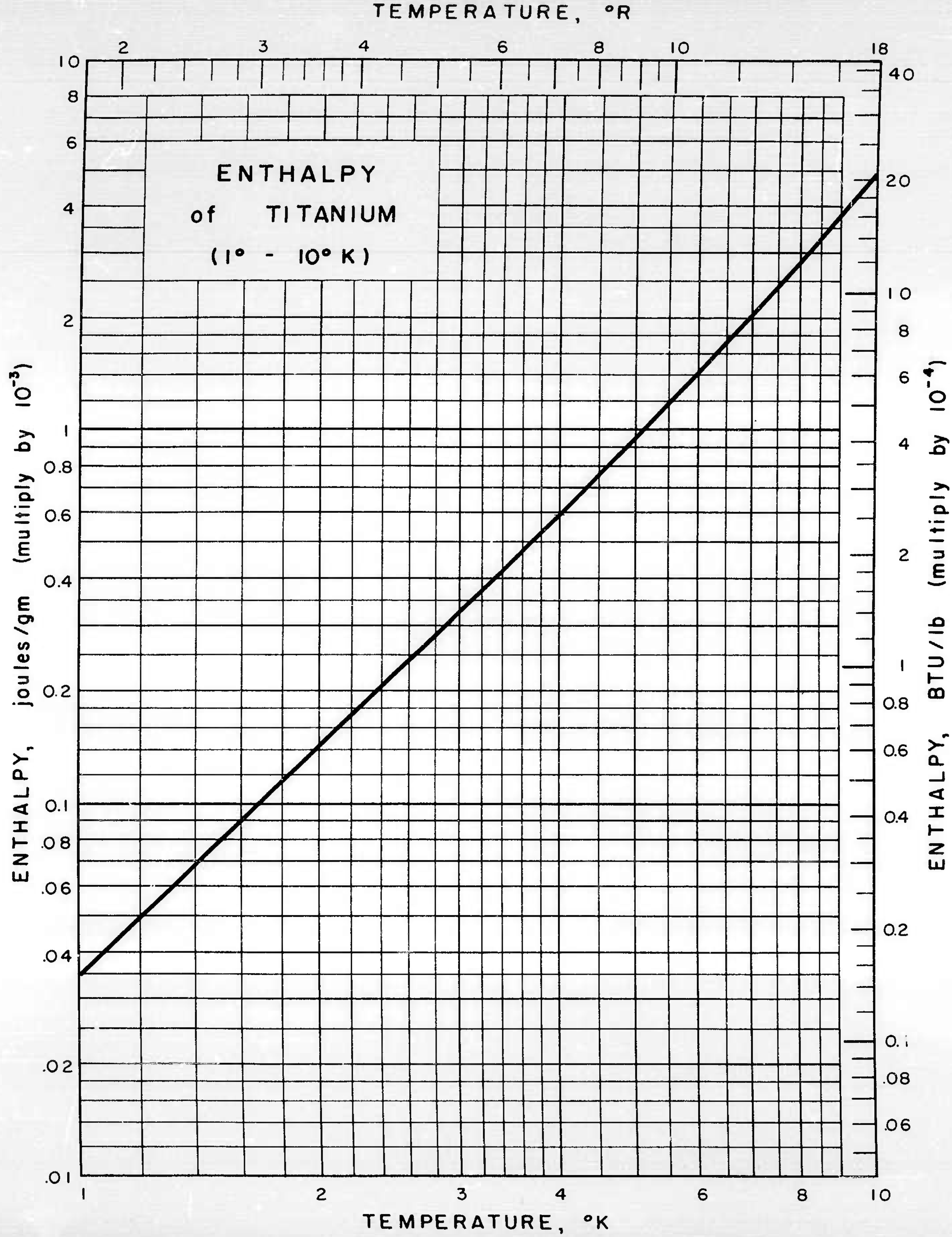
Table of Selected Values

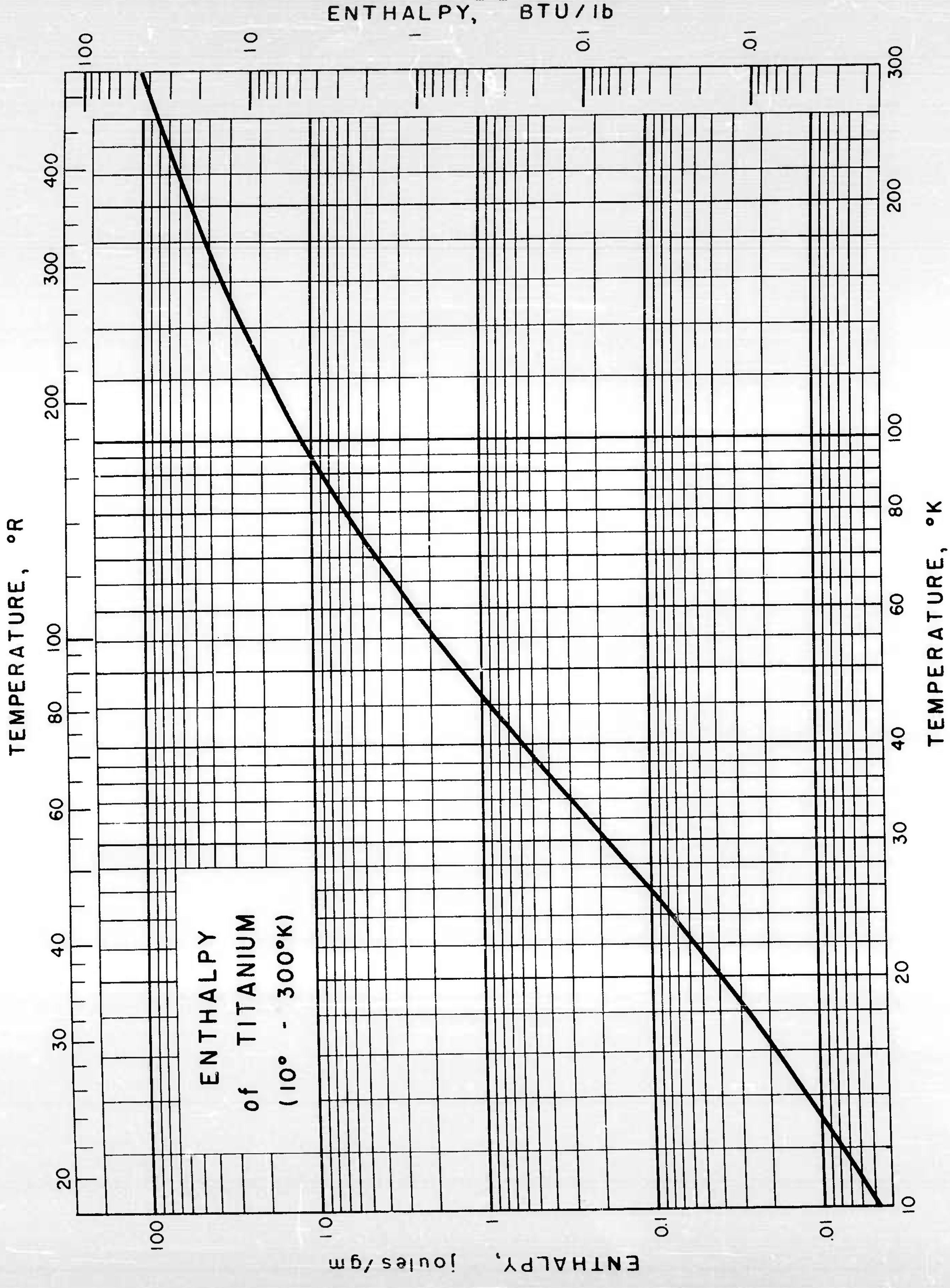
Temp. °K	C_p j/gm-°K	H j/gm	Temp. °K	C_p j/gm-°K	H j/gm
1	0.000 071	0.000 035	70	0.189	4.27
2	.000 146	.000 143	80	.230	6.37
3	.000 226	.000 329	90	.267	8.86
4	.000 317	.000 599	100	.300	11.69
6	.000 54	.001 45	120	.352	18.24
8	.000 84	.002 81	140	.391	25.69
10	.001 26	.004 89	160	.422	33.84
15	.003 3	.015 6	180	.446	42.54
20	.007 0	.040	200	.465	51.66
25	.013 4	.090	220	.480	61.11
30	.024 5	.182	240	.493	70.84
40	.057 1	.581	260	.504	80.82
50	.099 2	1.358	280	.514	91.01
60	.146 7	2.592	300	.522	101.39

RJC Issued: 12-16-59


TEMPERATURE, °R
2
3
4
6
8
10
18
2.0
1.0
0.8
0.6
0.4
0.3
0.2
0.1
.08
SPECIFIC HEAT
of TITANIUM
(1° - 10°K)
0.4
0.3
0.2
0.1
.08
.06
.04
.03
.02
SPECIFIC HEAT (Cp), joules/gm °K (multiply by 10⁻³)
SPECIFIC HEAT (Cp), BTU/lb °R (multiply by 10⁻³)
1
2
3
4
6
8
10
TEMPERATURE, °K


SPECIFIC HEAT (Cp), BTU/lb °R (multiply by 10⁻¹)
SPECIFIC HEAT of TITANIUM (10° - 300°K)
TEMPERATURE, °R
TEMPERATURE, °K
SPECIFIC HEAT (Cp), joules/gm °K


TEMPERATURE, °R
2
3
4
6
8
10
18
ENTHALPY
of TITANIUM
(1° - 10° K)
ENTHALPY, joules/gm (multiply by 10^{-3})
10
8
6
4
2
1
0.8
0.6
0.4
0.2
0.1
.08
.06
.04
.02
.01
ENTHALPY, BTU/lb (multiply by 10^{-4})
40
20
10
8
6
4
2
1
0.8
0.6
0.4
0.2
0.1
.08
.06
1
2
3
4
6
8
10
TEMPERATURE, °K


ENTHALPY, BTU/lb
ENTHALPY of TITANIUM (10° - 300°K)
TEMPERATURE, °R
TEMPERATURE, °K
ENTHALPY, joules/gm

SPECIFIC HEAT, ENTHALPY of ACTIVATED CHARCOAL

Source of Data:

Simon, F. and Swain, R. C., Z. physik. Chem. B28, 189-98 (1935)

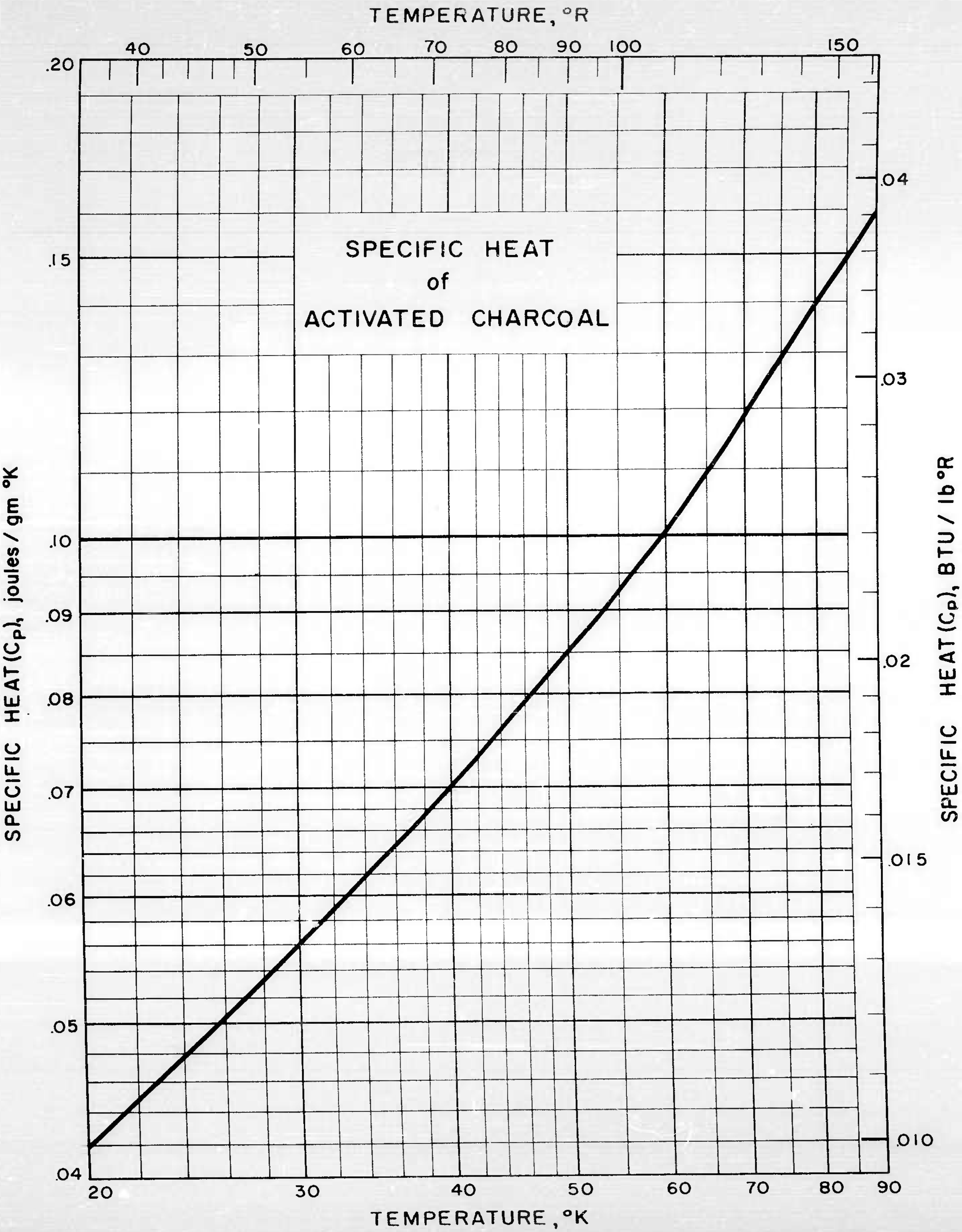
Comments:

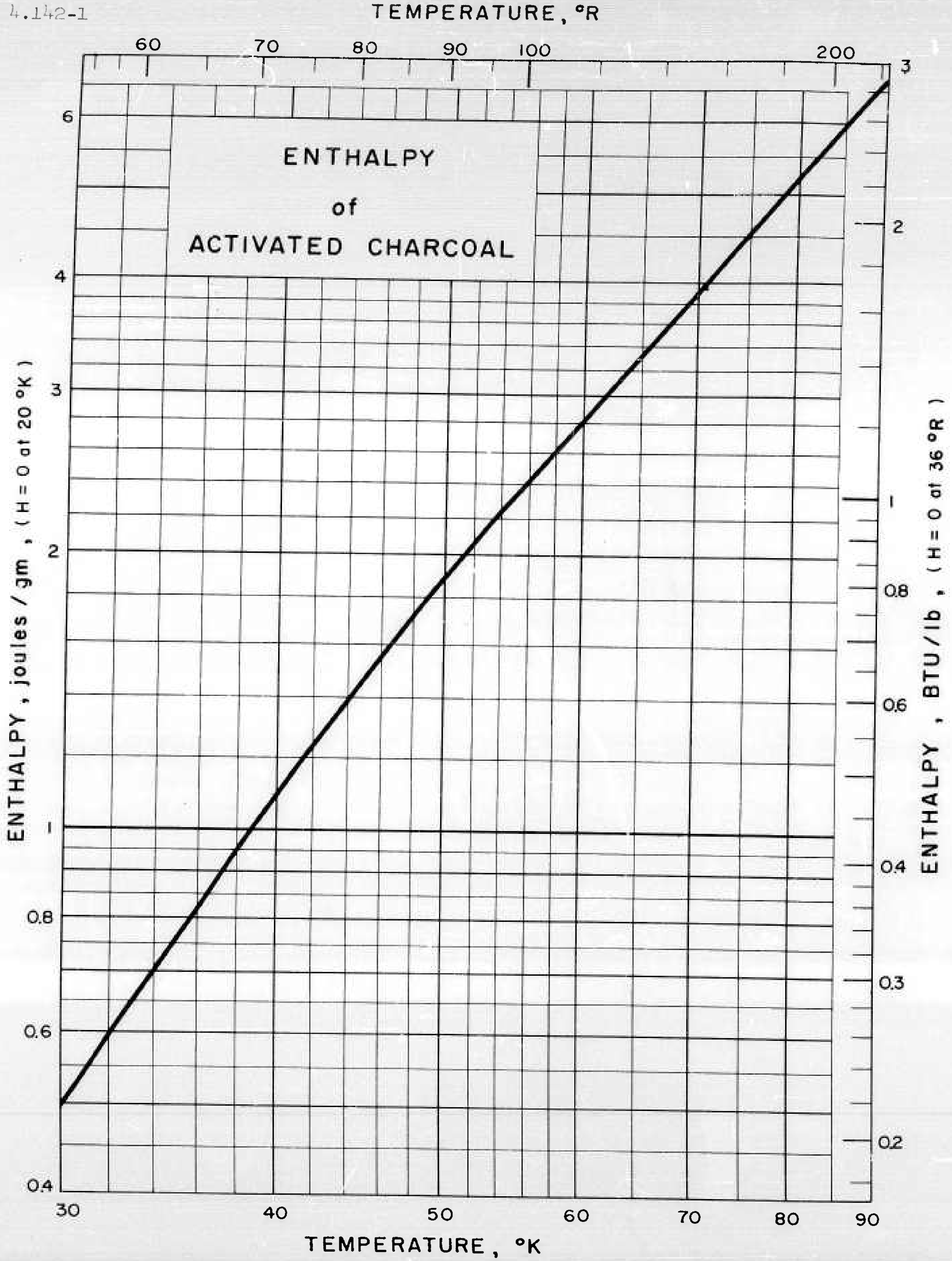
The values in the table below do not represent precise measurements and were made on a sample not fully characterized. The values are much higher than those for graphite. Since activated charcoal varies in structure and area, one may infer that the specific heat might also vary considerably from sample to sample.

Table of Selected Values

Temp. °K	C_p j/gm-°K	$H-H_{20}$ j/gm
20	0.042	
30	.056	0.49
40	.070	1.1
50	.087	1.9
60	.10	2.8
70	.12	3.9
80	.14	5.2
90	.16	6.7

JJG/JRC Issued: 9/2/59
Revised: 1/20/60


TEMPERATURE, °R
40
50
60
70
80
90
100
150
SPECIFIC HEAT
of
ACTIVATED CHARCOAL
SPECIFIC HEAT (C_p), joules / gm °K
.20
.15
.10
.09
.08
.07
.06
.05
.04
SPECIFIC HEAT (C_p), BTU / lb °R
.04
.03
.02
.015
.010
20
30
40
50
60
70
80
90
TEMPERATURE, °K


TEMPERATURE, °R
60
70
80
90
100
200
ENTHALPY
of
ACTIVATED CHARCOAL
ENTHALPY, joules / gm, (H = 0 at 20 °K)
6
4
3
2
1
0.8
0.6
0.4
ENTHALPY, BTU/lb, (H = 0 at 36 °R)
3
2
1
0.8
0.6
0.4
0.3
0.2
30
40
50
60
70
80
90
TEMPERATURE, °K

SPECIFIC HEAT, ENTHALPY of CARBON (GRAPHITE)

Sources of Data:

Keesom, P. H. and Pearlman, N.; Phys. Rev. 99, 1119-24 (1955)

De Sorbo, W. and Tyler, W., J. Chem. Phys. 21, 1660-3 (1953)

Other References:

Bergenlid, V., Hill, R. W., Webb, F. J. and Wilks, J., Phil. Mag. 45, 851-4 (1954)

Dewar, J., Proc. Roy. Soc. (London) A76, 325 (1904)

Ewald, R., Ann. phys. (4) 1213 (1914)

Jacobs, C. J. and Parks, G. S., J. Am. Chem. Soc. 56, 1513 (1934)

Koref, F., Ann. Phys. (4) 36, 49 (1911)

Richards, T. W. and Jackson, F. G., Z. physik. Chem. 70, 414 (1910)

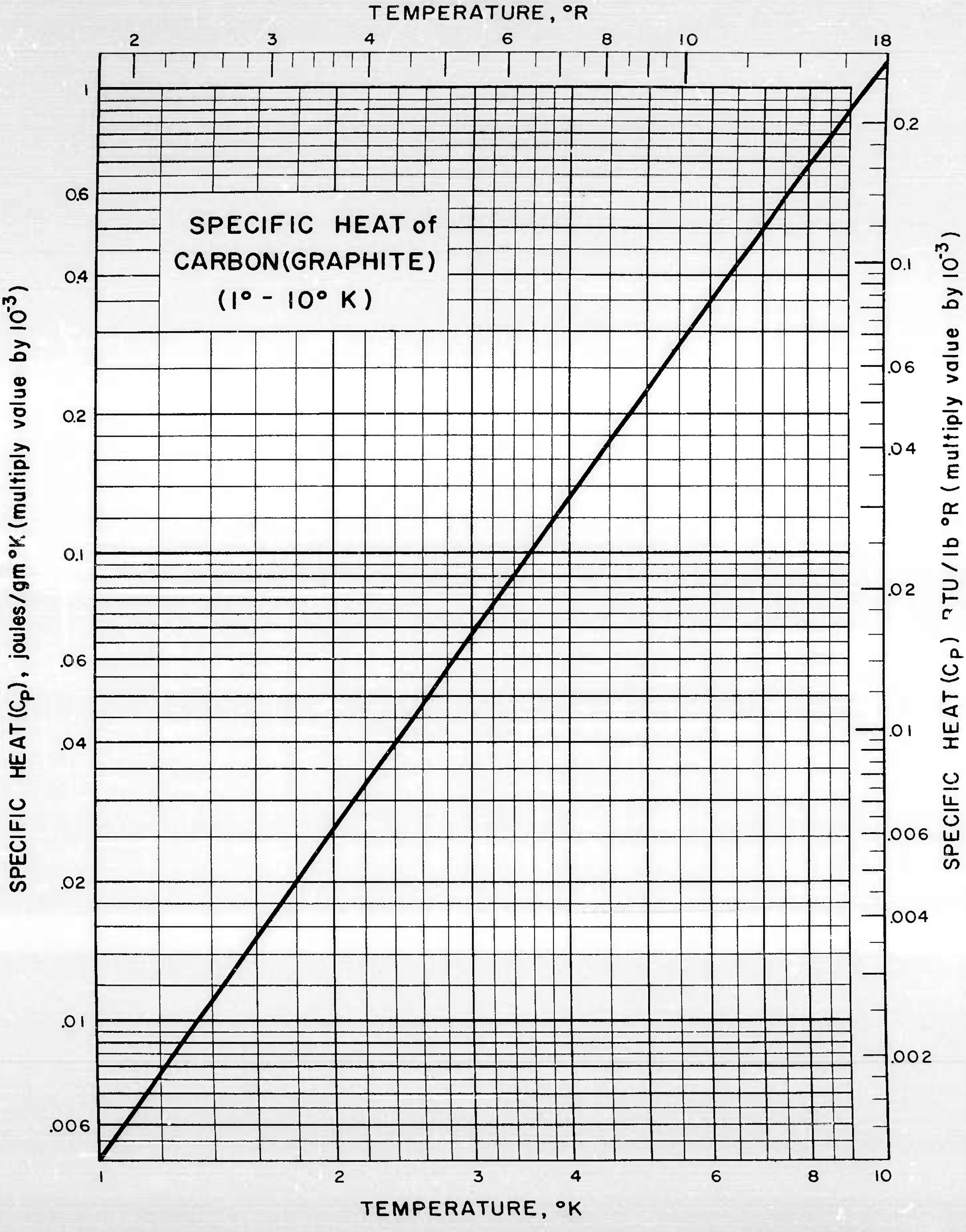
Comments:

For $0 < T < 2°K$

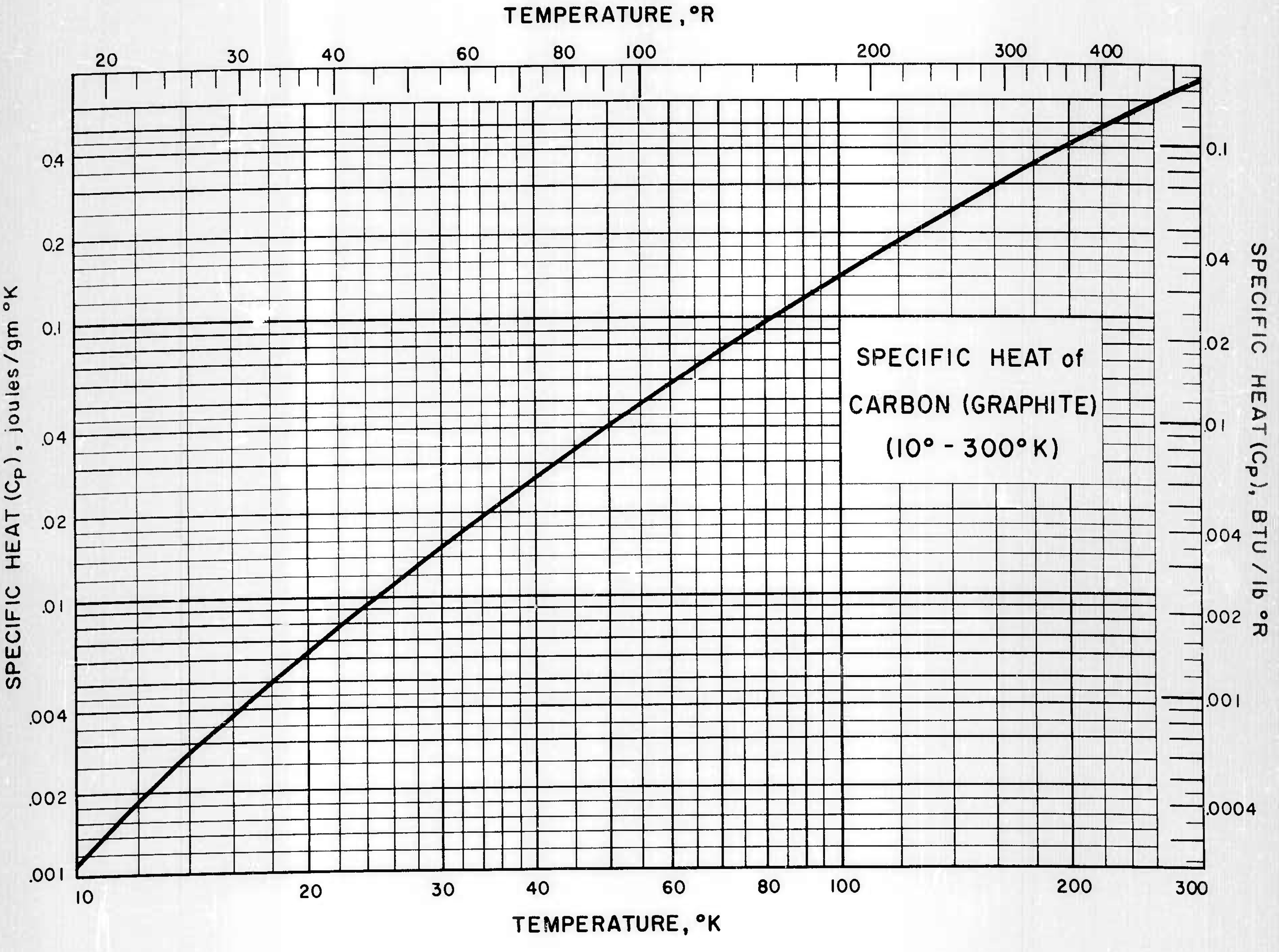
$$C_p = 162\ (T/391)^3 + 2.6 \times 10^{-6}\ T \text{ j/gm-°K}$$

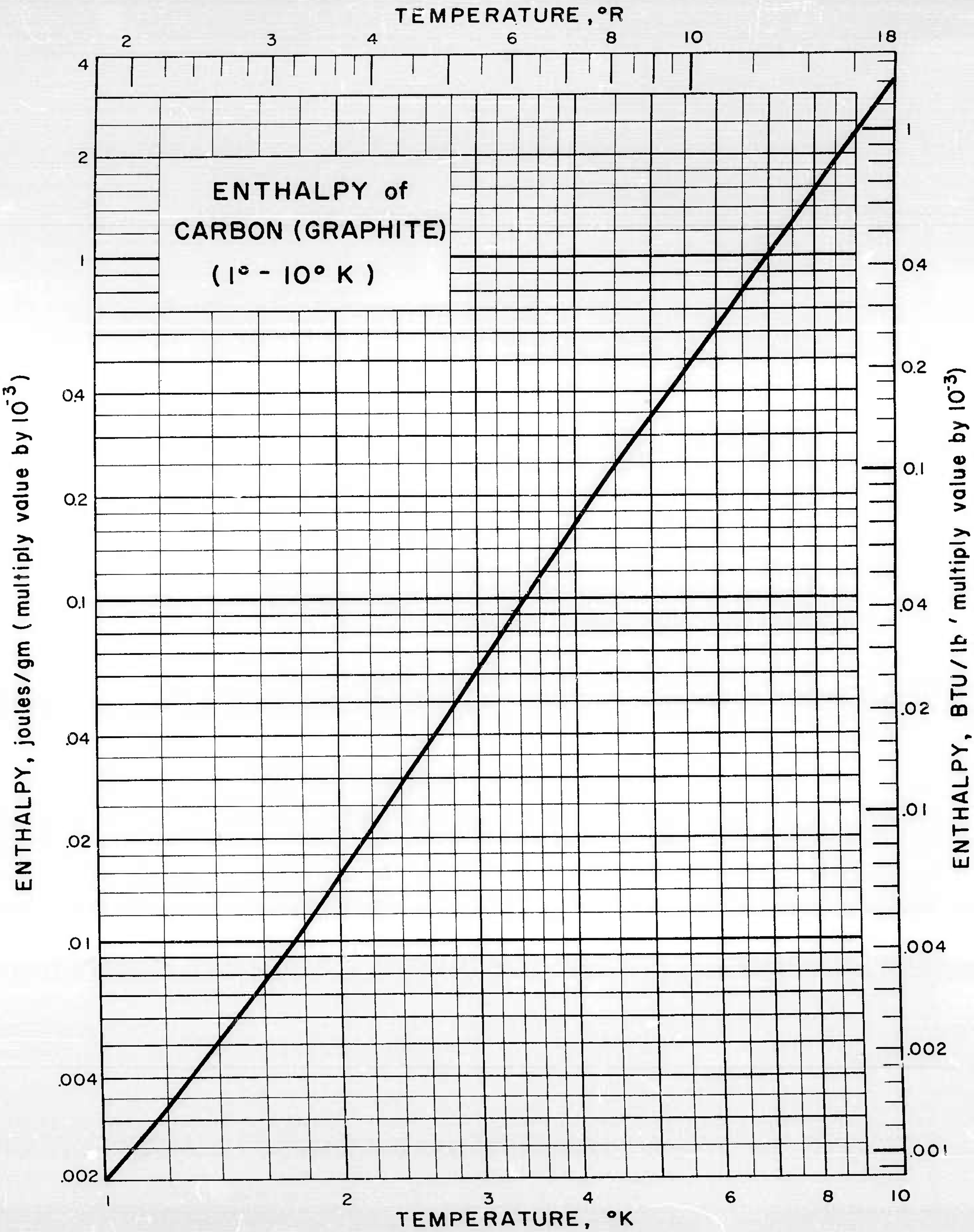
Temp. °K	C_p j/gm-°K	H j/gm	Temp. °K	C_p j/gm-°K	H j/gm
1	.000 005	.000 002	70	.077	1.87
2	.000 027	.000 016	80	.097	2.74
3	.000 070	.000 062	90	.118	3.81
4	.000 144	.000 168	100	.140	5.10
6	.000 33	.000 61	120	.188	8.37
8	.000 64	.001 56	140	.240	12.65
10	.001 14	.003 3	160	.296	18.0
15	.003 3	.014 2	180	.355	24.5
20	.006 3	.038	200	.414	32.2
25	.010 3	.079	220	.474	41.1
30	.015 5	.143	240	.535	51.2
40	.027	.36	260	.595	62.5
50	.042	.70	280	.656	75.0
60	.058	1.20	300	.716	88.7

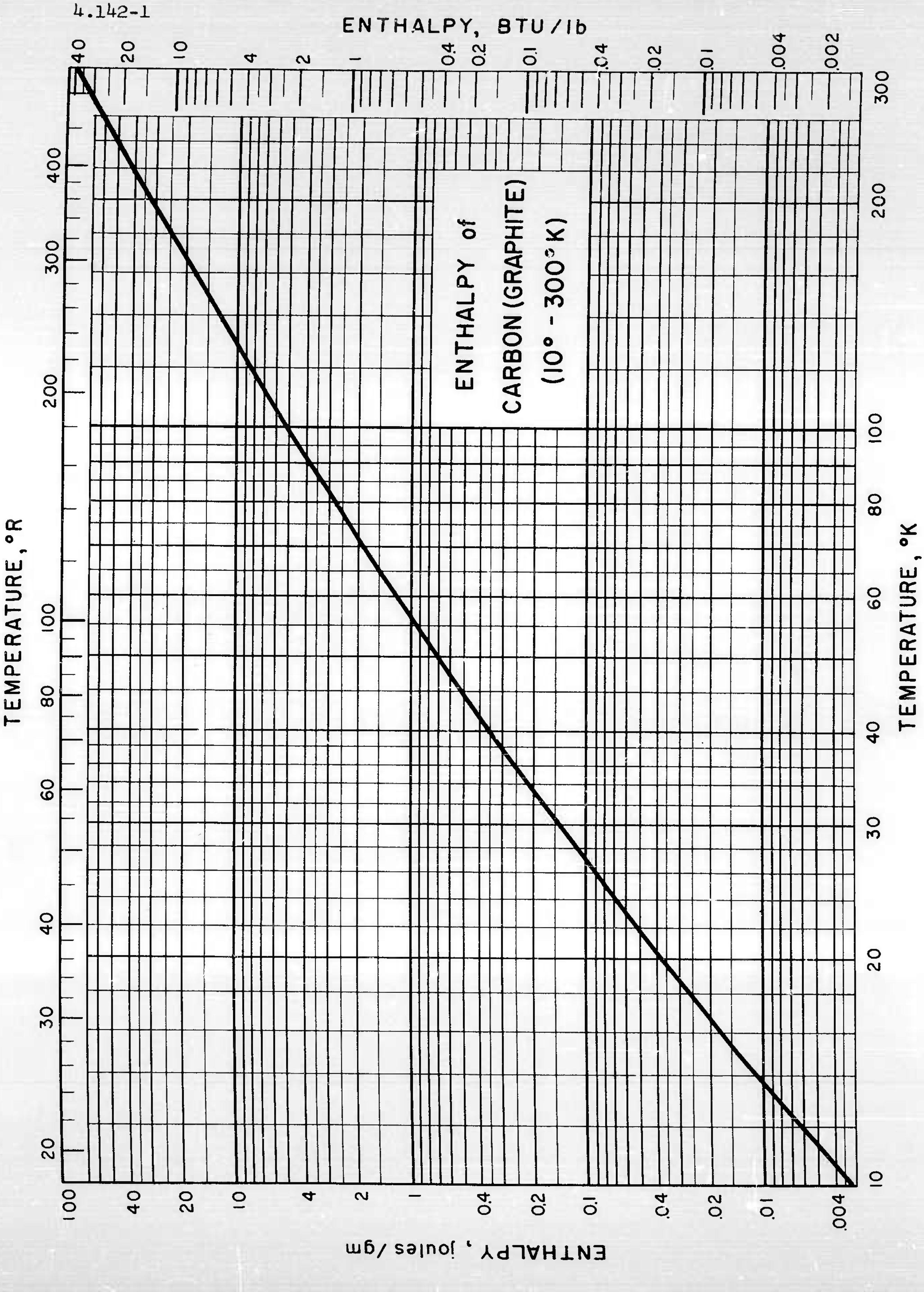
RJC/JJG Issued: 12-16-59
Revised: 5-20-60


TEMPERATURE, °R
2
3
4
6
8
10
18
SPECIFIC HEAT of CARBON(GRAPHITE) (1° - 10° K)
SPECIFIC HEAT (C_p), joules/gm °K (multiply value by 10^{-3})
1
0.6
0.4
0.2
0.1
.06
.04
.02
.01
.006
SPECIFIC HEAT (C_p) BTU/lb °R (multiply value by 10^{-3})
0.2
0.1
.06
.04
.02
.01
.006
.004
.002
1
2
3
4
6
8
10
TEMPERATURE, °K

4.142-1


TEMPERATURE, °R
20
30
40
60
80
100
200
300
400
SPECIFIC HEAT of
CARBON (GRAPHITE)
(10° - 300° K)
SPECIFIC HEAT (C_p), joules/gm °K
0.4
0.2
0.1
.04
.02
.01
.004
.002
.001
SPECIFIC HEAT (C_p), BTU / lb °R
0.1
.04
.02
.01
.004
.002
.001
.0004
10
20
30
40
60
80
100
200
300
TEMPERATURE, °K


TEMPERATURE, °R
2
3
4
6
8
10
18
ENTHALPY of
CARBON (GRAPHITE)
(1° - 10° K)
ENTHALPY, joules/gm (multiply value by 10^{-3})
4
2
1
0.4
0.2
0.1
.04
.02
.01
.004
.002
ENTHALPY, BTU/lb (multiply value by 10^{-3})
1
0.4
0.2
0.1
.04
.02
.01
.004
.002
.001
1
2
3
4
6
8
10
TEMPERATURE, °K


ENTHALPY of
CARBON (GRAPHITE)
(10° - 300°K)
ENTHALPY, BTU/lb
40
20
10
4
2
1
0.4
0.2
0.1
.04
.02
.01
.004
.002
TEMPERATURE, °R
400
300
200
100
80
60
40
30
20
TEMPERATURE, °K
300
200
100
80
60
40
30
20
10
ENTHALPY, joules/gm
100
40
20
10
4
2
1
0.4
0.2
0.1
.04
.02
.01
.004

SPECIFIC HEAT, ENTHALPY of DIAMOND

Sources of Data:

Burk, D. L. and Friedberg, S. A., Phys. Rev. 111, 1275-82 (1958)

Desnoyers, J. E. and Morrison, J. A., Phil. Mag. 3, 42-8 (1958)

De Sorbo, W., J. Chem. Phys. 21, 876 (1953)

Other References:

Berman, R. and Poulter, J., J. Chem. Phys. 21, 1906-7 (1953)

Nernst, W., Ann. Physik. 36, 395-439 (1911)

Nernst, W. and Lindemann, F. A., Z. Elektrochem. 17, 817-27 (1911)

Pitzer, K. S., J. Chem. Phys. 6, 68-70 (1938)

Robertson, R., Fox, J. J. and Martin, A. E., Proc. Roy. Soc. (London) A157, 579-94 (1936)

Comments:

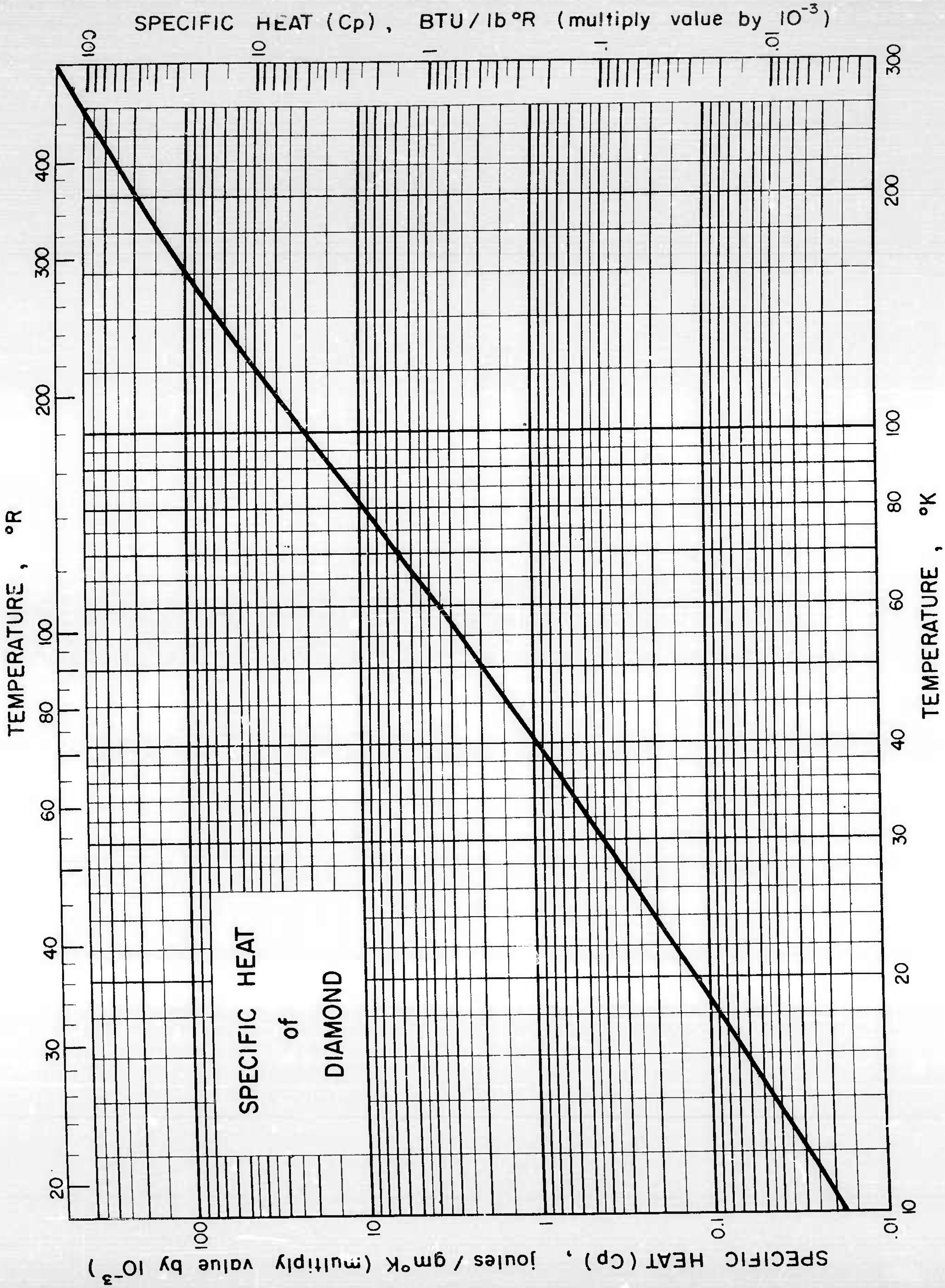
C_p values are without regard to ratio of Type I to Type II crystals used as sample.

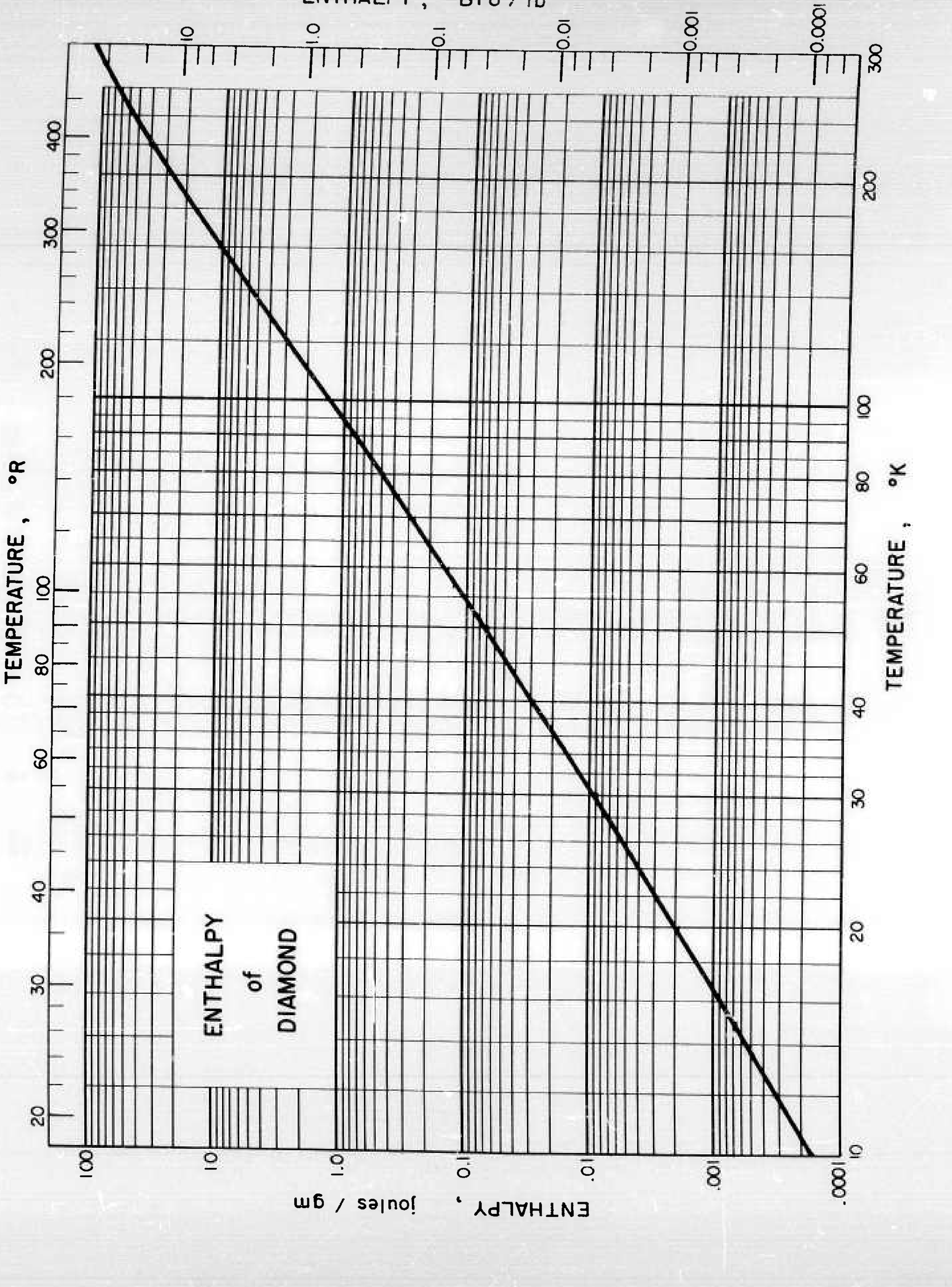
The Debye Temperature at 0°K, Θ_0, used in theoretical calculations of specific heats near 0°K, for diamond = 2100 ± 140.

Table of Selected Values

Temp. °K	C_p j/gm-°K	H j/gm	Temp. °K	C_p j/gm-°K	H j/gm
10	0.000 018	0.000 17	100	0.0204	1.31
15	.000 053	.000 66	120	.0390	2.97
20	.000 122	.001 87	140	.0658	5.94
25	.000 235	.004 38	160	.102	10.7
30	.000 404	.008 87	180	.145	17.8
40	.000 979	.027 8	200	.195	27.5
50	.001 95	.068 8	220	.252	40.3
60	.003 41	.144	240	.314	56.6
70	.005 92	.276	260	.380	76.5
80	.009 34	.489	280	.447	100
90	.014 0	.821	300	.518	128

RJC/JJG/VDA Issued: 10-13-59
Revised: 5-20-60


SPECIFIC HEAT (Cp), BTU/lb °R (multiply value by 10^{-3})
SPECIFIC HEAT (Cp), joules / gm°K (multiply value by 10^{-3})
TEMPERATURE, °R
TEMPERATURE, °K
SPECIFIC HEAT
of
DIAMOND
100
10
1
.1
.01
400
300
200
80
60
40
30
20
300
200
100
80
60
40
30
20
10


ENTHALPY of DIAMOND
ENTHALPY , BTU / lb
10
1.0
0.1
0.01
0.001
0.0001
TEMPERATURE , °R
20
30
40
60
80
100
200
300
400
TEMPERATURE , °K
10
20
30
40
60
80
100
200
300
ENTHALPY , joules / gm
100
10
1.0
0.1
.01
.001
.0001

SPECIFIC HEAT and ENTHALPY of VITREOUS SILICA

(Silica Glass, Quartz Glass)

Sources of Data:

Simon, F., Ann. Physik (4) 68, 241-80 (1922)

Simon, F. and Lange, F., Z. physik. 38, 227-36 (1926)

Westrum, E. F., data reproduced in Lord, R. C. and Morrow, J. C., J. Chem. Phys. 26, 230 (1957)

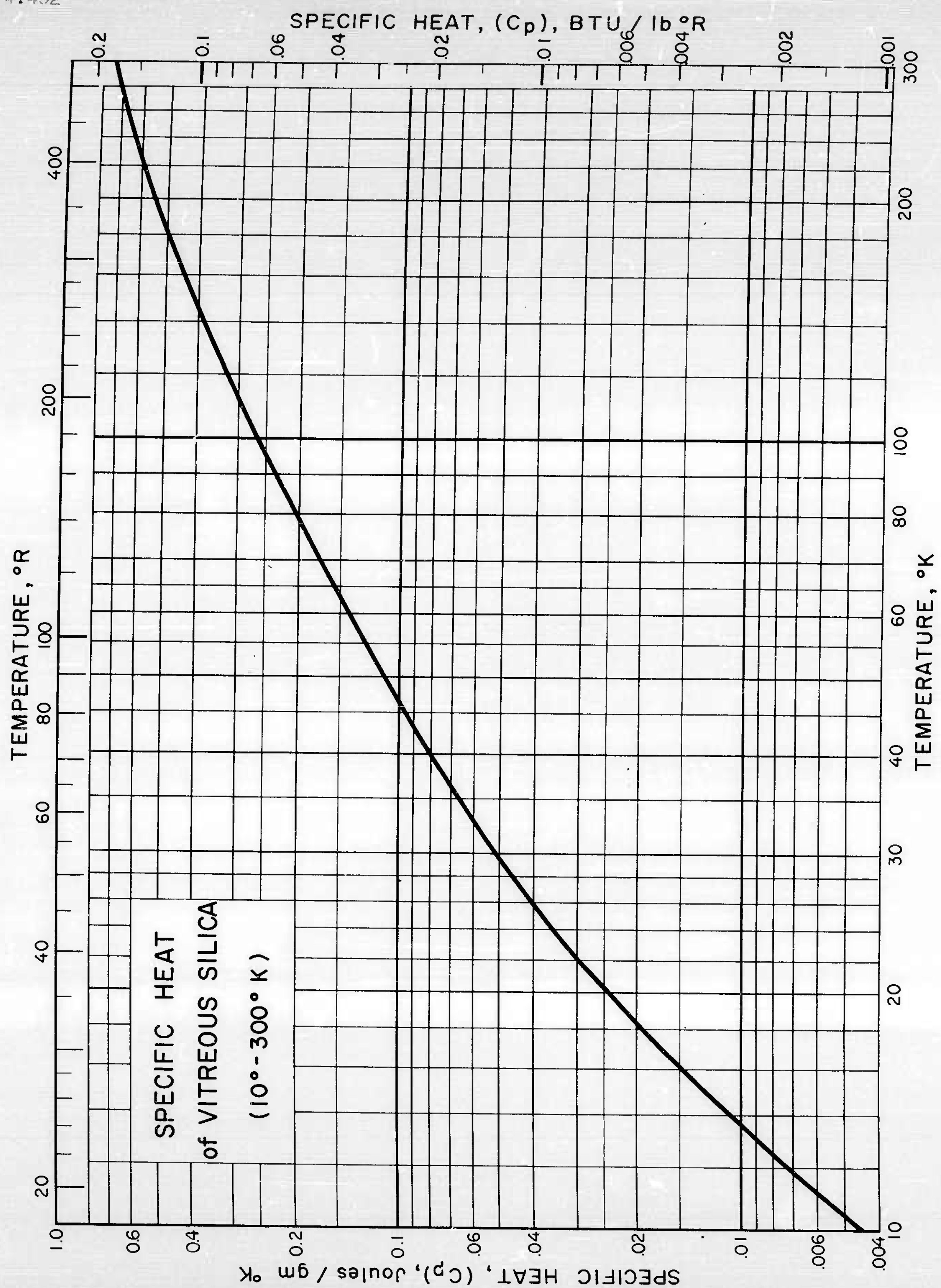
Other References:

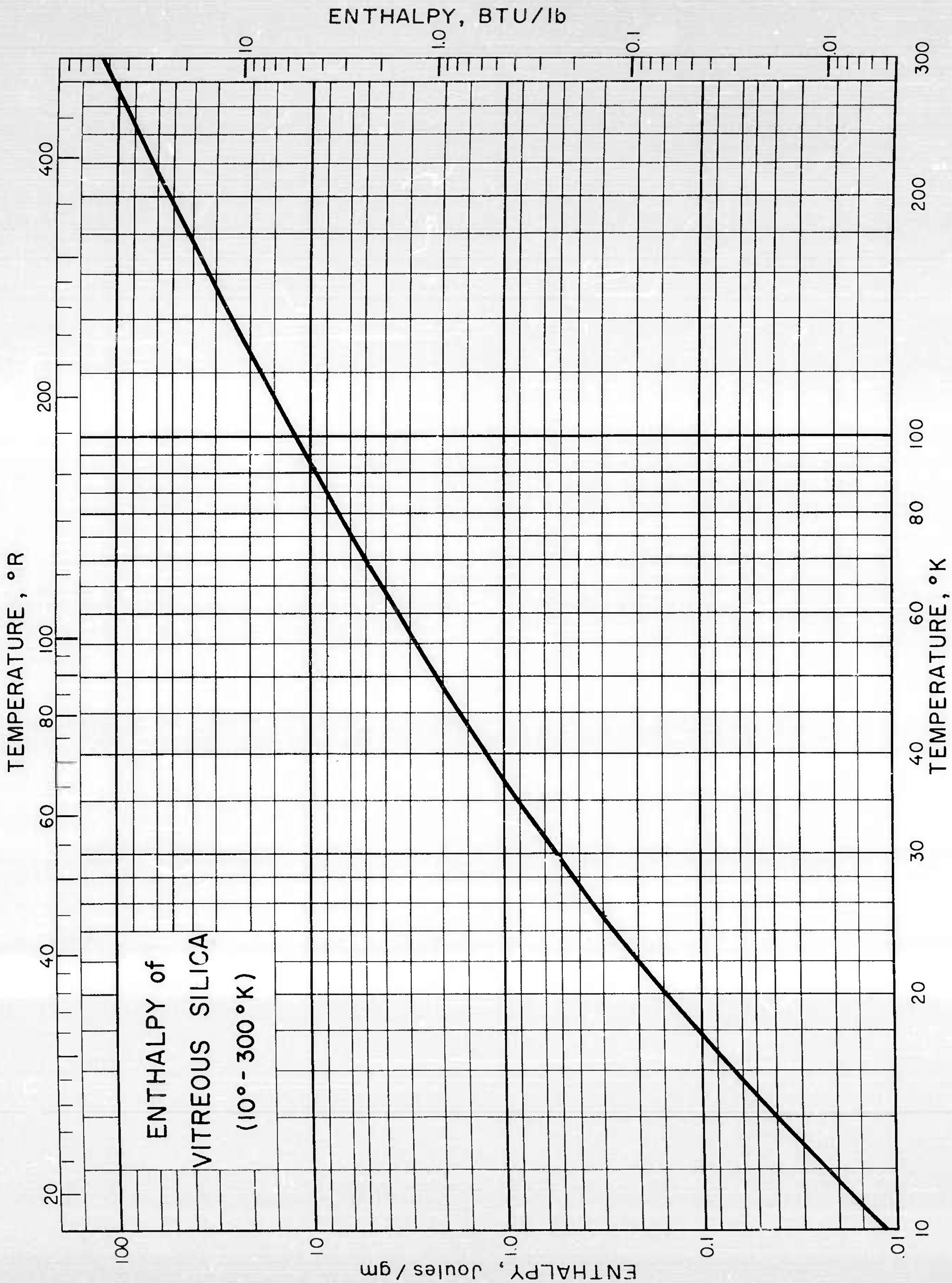
Nernst, W., Sitzber. kgl. preuss. Akad. Wiss., 306 (1911)

Table of Selected Values

Temp. °K	C_p j/gm-°K	H j/gm	Temp. °K	C_p j/gm-°K	H j/gm
10	0.0045	0.011	100	0.268	11.57
15	.0126	0.052	120	.331	17.56
20	.0244	0.143	140	.391	24.77
25	.0379	0.299	160	.446	33.14
30	.0519	0.524	180	.497	42.6
40	.0808	1.186	200	.544	53.0
50	.111	2.15	220	.588	64.3
60	.141	3.41	240	.629	76.5
70	.172	4.97	260	.668	89.5
80	.204	6.85	280	.704	103.2
90	.236	9.05	300	.738	117.6

RJC Issued: 6/15/59
Revised: 5/20/60


SPECIFIC HEAT, (Cp), BTU / lb °R
0.2
0.1
.06
.04
.02
.01
.006
.004
.002
.001
TEMPERATURE, °R
400
200
100
80
60
40
20
TEMPERATURE, °K
300
200
100
80
60
40
30
20
10
SPECIFIC HEAT
of VITREOUS SILICA
(10°-300° K)
SPECIFIC HEAT, (Cp), Joules / gm °K
1.0
0.6
0.4
0.2
0.1
.06
.04
.02
.01
.006
.004


ENTHALPY, BTU/lb
10
1.0
0.1
.01
TEMPERATURE, °R
400
200
100
80
60
40
20
TEMPERATURE, °K
300
200
100
80
60
40
30
20
10
ENTHALPY of
VITREOUS SILICA
(10°-300°K)
ENTHALPY, Joules/gm
100
10
1.0
0.1
.01

SPECIFIC HEAT and ENTHALPY of LEAD

Sources of Data:

Horowitz, M., Silvidi, A. A., Malaker, S. F. and Daunt, J. G., Phys. Rev. 88, 1182 (1952)

Meads, P. F., Forsythe, W. R. and Giauque, W. F., J. Am. Chem. Soc. 63, 1902 (1941)

Other References:

Behn, U., Ann. Physik (3) 66, 237 (1898)

Bronson, H. L. and Wilson, A. J. C., Can. J. Research A14, 181 (1936)

Clement, J. R. and Quinnell, E. H., Phys. Rev. 85, 502 (1952)

Dolacek, R. L., Conf. de Physique des Basses Temperatures, Paris (1955)

Eucken, A. and Schwers, F., Verhandl. deut. physik. Ges. 15, 578 (1913)

Griffiths, E. G. and Griffiths, E., Proc. Roy. Soc. (London) A90, 557 (1914)

Keesom, W. H. and Andrews, D. H., Commun. Kamerlingh Onnes Lab. Univ. Leiden 17, No. 185a, (1924)

Keesom, W. H. and Onnes, H. K., Commun. Kamerlingh Onnes Lab. Univ. Leiden No. 143, (1913-14) and Verslag Koninkl. Akad. Wetenschap. Amsterdam 23, 798-812 (1914)

Keesom, W. H. and Van den Ende, J. N., Physik. Z. 29, 896 (1928)

Keesom, W. H. and Van den Ende, J. N., Commun. Kamerlingh Onnes Lab. Univ. Leiden No. 203d, 25 (1930) and Proc. Acad. Sci. Amsterdam 33, 243 (1930)

Keesom, W. H. and Van den Ende, J. N., Commun. Kamerlingh Onnes Lab. Univ. Leiden No. 213c, (1931) and Proc. Acad. Sci. Amsterdam 34, 210 (1931)

Koref, F., Ann. Physik (4) 36, 49 (1911)

Mendelssohn, K. and Simon, F., Z. physik. Chem. B16, 72 (1932)

Nernst, W., Sitzber. klg. preuss. Akad. Wiss., 262 (1910)

(continued)

SPECIFIC HEAT and ENTHALPY of LEAD (Cont.)

Other References (Cont.)

Nernst, W. Sitzber. kgl. preuss. Akad. Wiss., 306 (1911)

Nernst, W. and Lindemann, F. A., Sitzber. kgl. preuss. Akad. Wiss., 494 (1911)

Richards, T. W. and Jackson, F. G., Z. physik. Chem. 70, 414 (1910)

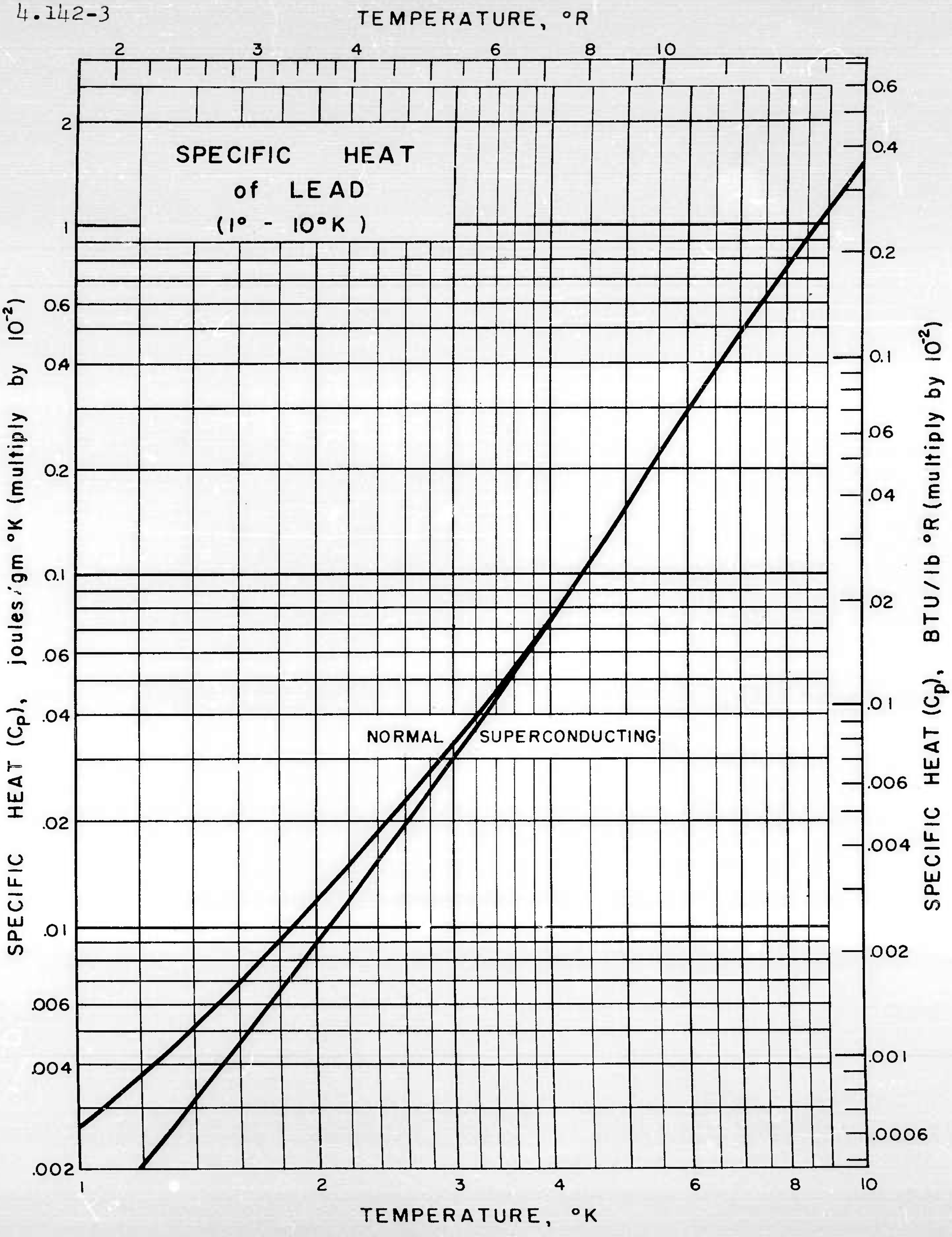
Schmitz, H. E., Proc. Roy. Soc. (London) 72, 177 (1903)

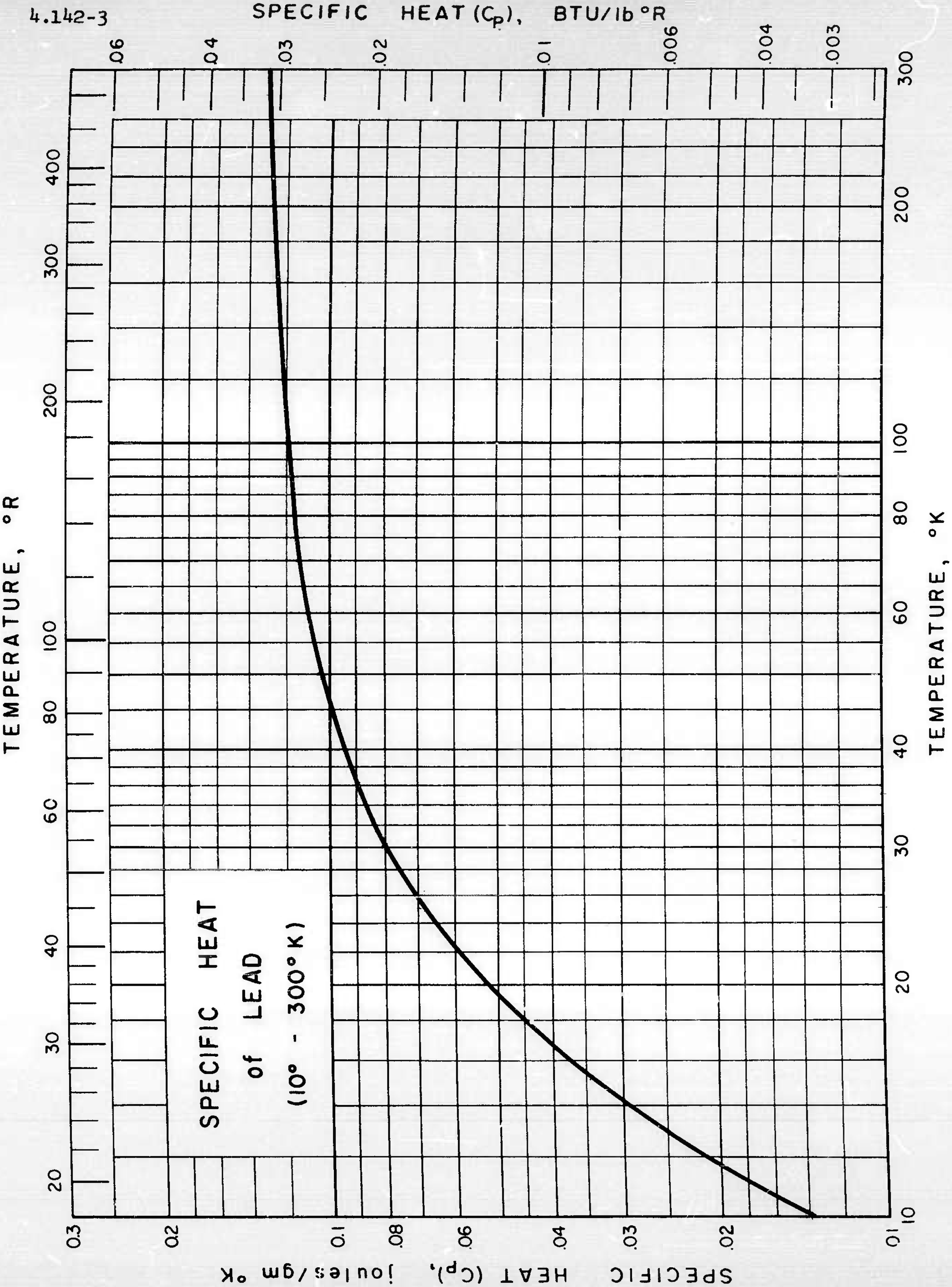
Simon, F., Z. physik. Chem. 110, 572 (1924)

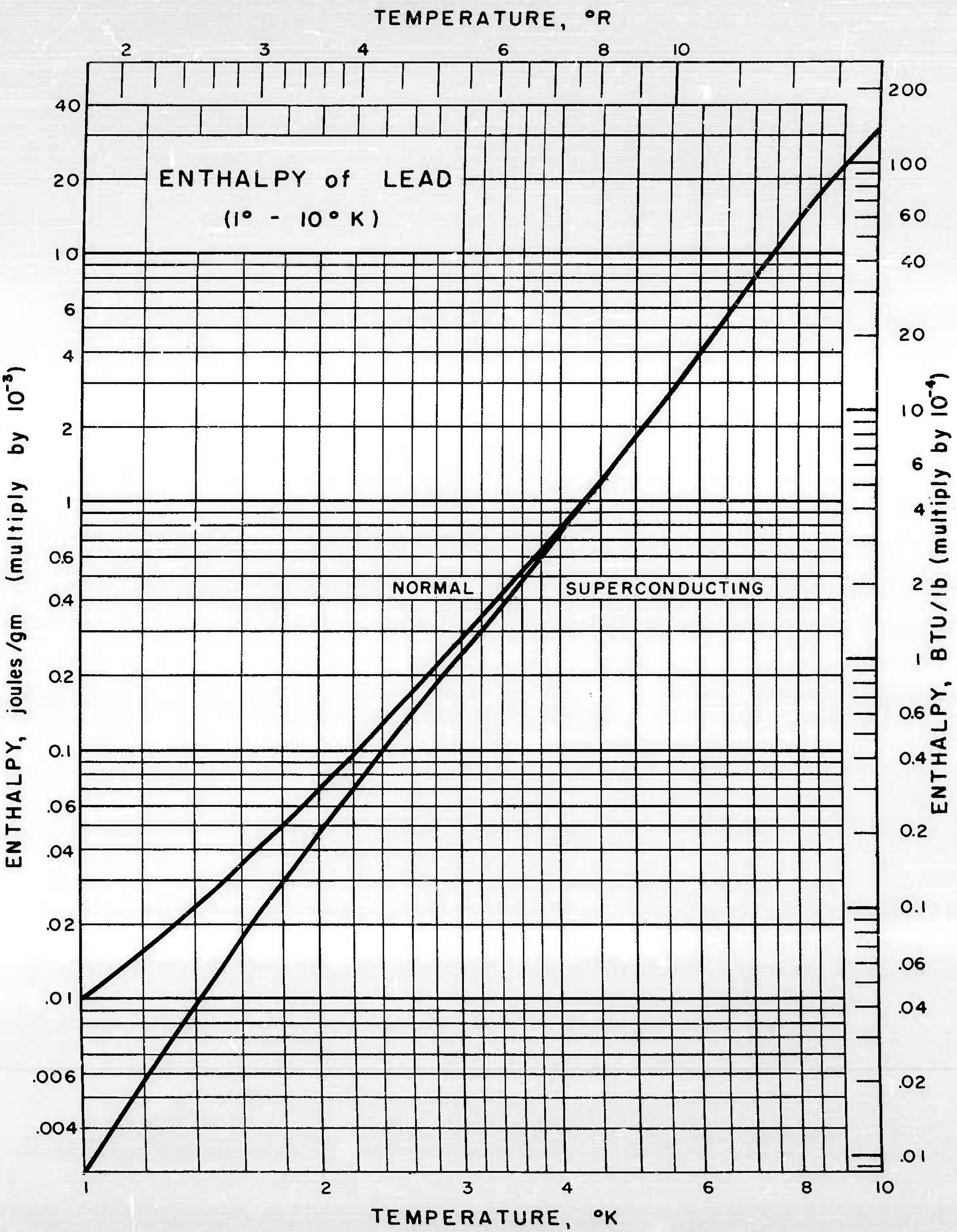
Table of Selected Values

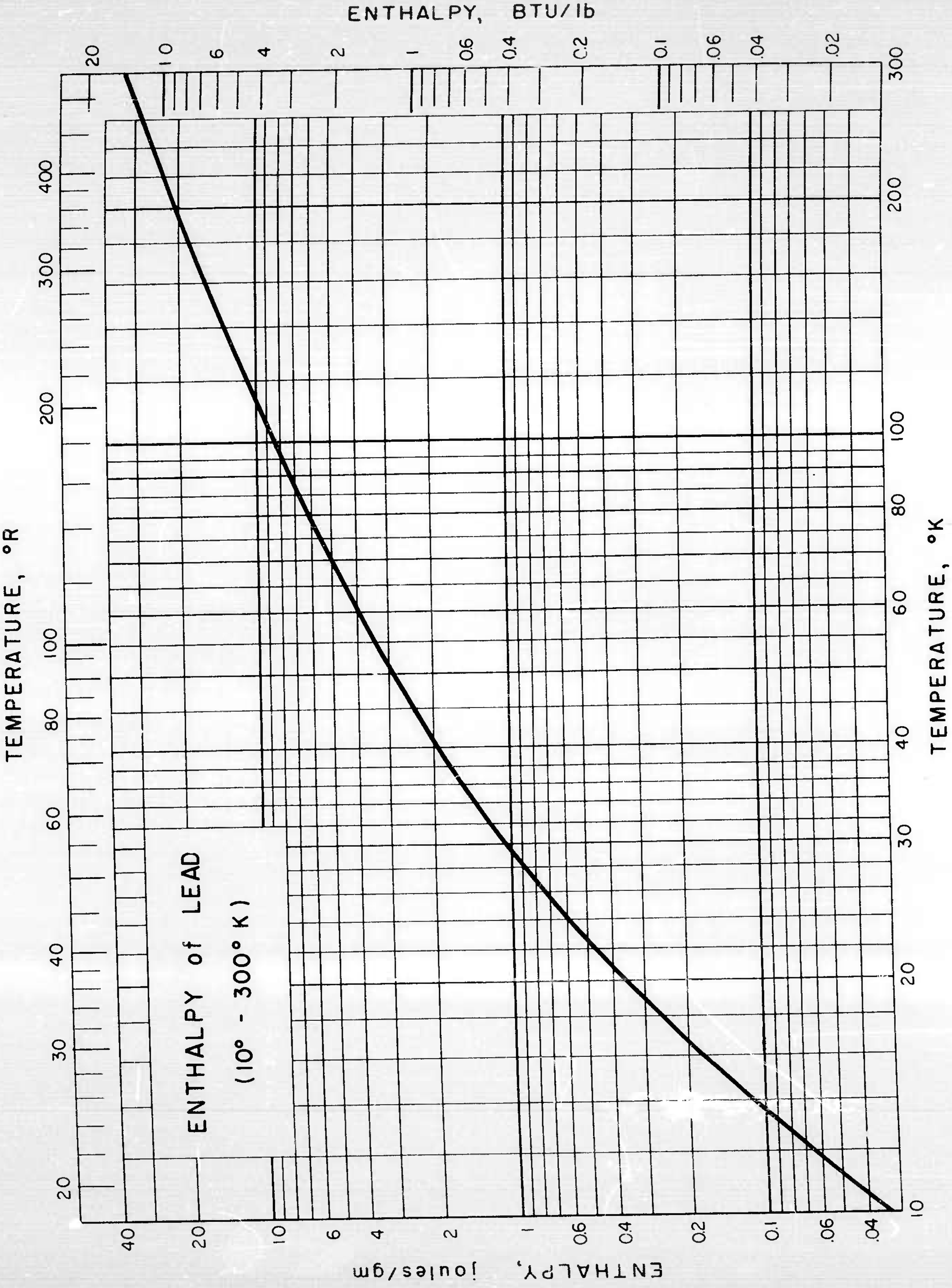
T	C_p, j/gm °K		H, j/gm		T	C_p	H
°K	Normal	Super Conducting	Normal	Super Conducting	°K	j/gm °K Normal	j/gm Normal
1	0.000 026	0.000 012	0.000 010	0.000 003	50	0.103	2.91
2	.000 12	.000 09	.000 07	.000 05	60	.108	3.97
3	.000 33	.000 31	.000 28	.000 23	70	.112	5.07
4	.000 7	.000 7	.000 8	.000 7	80	.114	6.20
5	.001 5	.001 5	.001 8	.001 8	90	.116	7.35
6	.002 9	.003 0	.003 9	.004 0	100	.118	8.53
7	.004 8	.005 0	.008	.008	120	.120	10.91
8	.007 3		.014		140	.121	13.32
10	.013 7		.034		160	.123	15.76
15	.033 5		.150		180	.124	18.22
20	.053 1		.368		200	.125	20.71
25	.068 1		.672		220	.126	23.21
30	.079 6		1.042		240	.127	25.73
35	.088 2		1.462		260	.128	28.28
40	.094 4		1.920		280	.129	30.85
45	.099 1		2.405		300	.130	33.43

RJC Issued: 6-15-59


TEMPERATURE, °R
2
3
4
6
8
10
SPECIFIC HEAT
of LEAD
(1° - 10°K)
NORMAL
SUPERCONDUCTING
SPECIFIC HEAT (C_p), joules/gm °K (multiply by 10^{-2})
2
1
0.6
0.4
0.2
0.1
.06
.04
.02
.01
.006
.004
.002
SPECIFIC HEAT (C_p), BTU/lb °R (multiply by 10^{-2})
0.6
0.4
0.2
0.1
.06
.04
.02
.01
.006
.004
.002
.001
.0006
1
2
3
4
6
8
10
TEMPERATURE, °K


SPECIFIC HEAT of LEAD (10° - 300° K)
SPECIFIC HEAT (C_p), BTU/lb °R
.06
.04
.03
.02
.01
.006
.004
.003
TEMPERATURE, °R
400
300
200
100
80
60
40
30
20
TEMPERATURE, °K
300
200
100
80
60
40
30
20
10
SPECIFIC HEAT (C_p), joules/gm °K
0.3
0.2
0.1
.08
.06
.04
.03
.02
0.1


TEMPERATURE, °R
2
3
4
6
8
10
ENTHALPY of LEAD
(1° - 10° K)
NORMAL
SUPERCONDUCTING
ENTHALPY, joules/gm (multiply by 10^{-3})
40
20
10
6
4
2
1
0.6
0.4
0.2
0.1
.06
.04
.02
.01
.006
.004
ENTHALPY, BTU/lb (multiply by 10^{-4})
200
100
60
40
20
10
6
4
2
1
0.6
0.4
0.2
0.1
.06
.04
.02
.01
1
2
3
4
6
8
10
TEMPERATURE, °K


ENTHALPY, BTU/lb
TEMPERATURE, °R
TEMPERATURE, °K
ENTHALPY, joules/gm
ENTHALPY of LEAD
(10° - 300° K)

SPECIFIC HEAT, ENTHALPY of TIN (white)

Sources of Data:

Corak, W. S. and Satterwaite, C. B., Phys. Rev. 102, 662 (1956)
Goodman, B. B., Compt. rend. 244, 2899 (1957)
Keesom, W. H. and Van den Ende, J. N., Proc. Acad. Sci. Amsterdam 35, 143 (1932)
Lange, F., Z. physik. Chem. 110, 343 (1924)
Rodebush, W. H., J. Am. Chem. Soc. 45, 1413 (1923)

Other References:

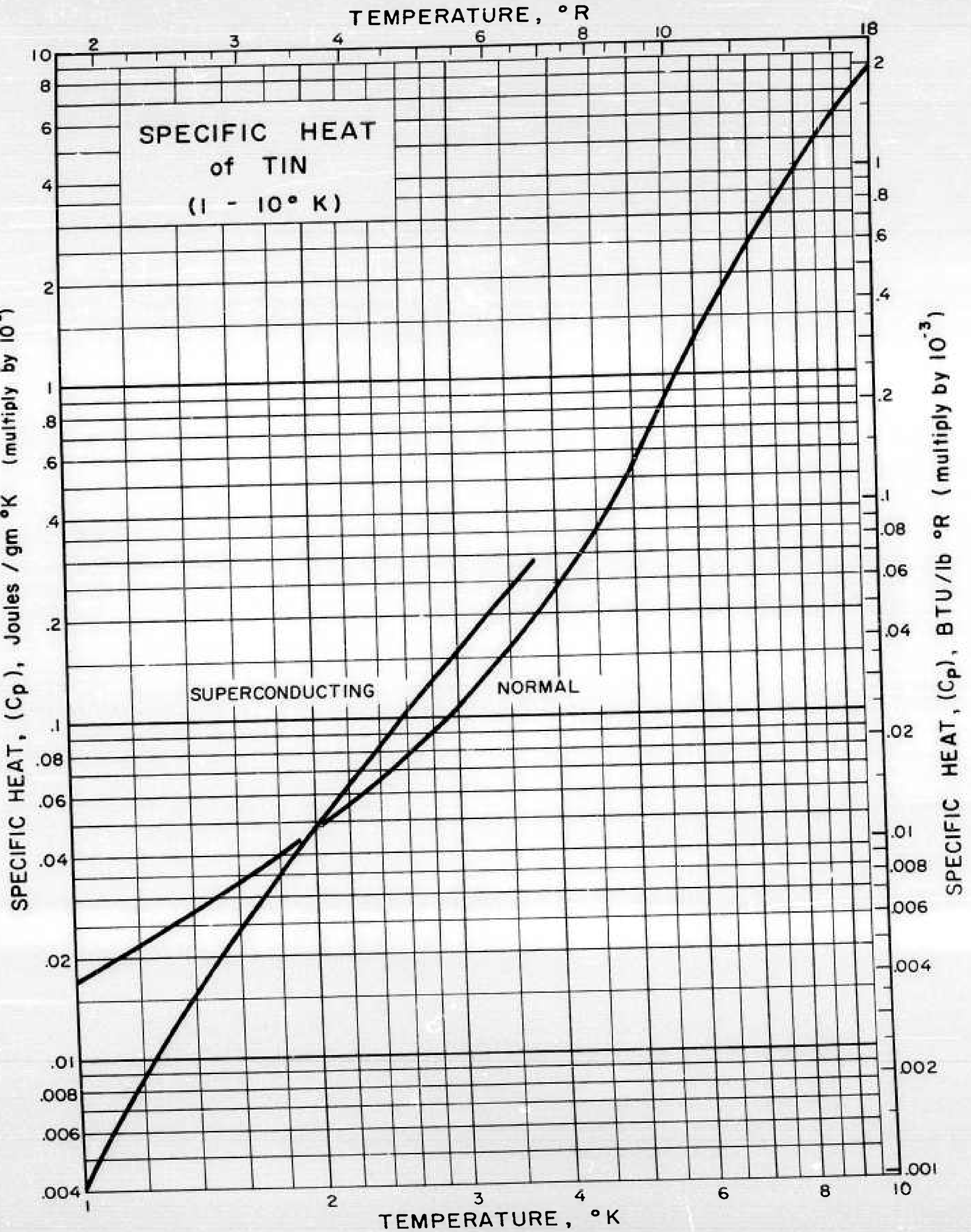
Brönsted, J. N., Z. physik. Chem. 88, 479 (1914)
Keesom, W. H. and Kok, J. A., Proc. Acad. Sci. Amsterdam 35, 743 (1932)
Keesom, W. H. and Van Laer, P. H., Physica 3, 371 (1936)
Keesom, W. H. and Van Laer, P. H., Physica 4, 487 (1937)
Keesom, W. H. and Van Laer, P. H., Physica 5, 193 (1938)
Ramanathan, K. G. and Srinivasan, T. M., Phil. Mag. 46, 338 (1955)
Richards, T. W. and Jackson, R. G., Z. physik. Chem. 70, 414 (1910)
Schmitz, H. E., Proc. Roy. Soc. (London) 72, 177 (1903)

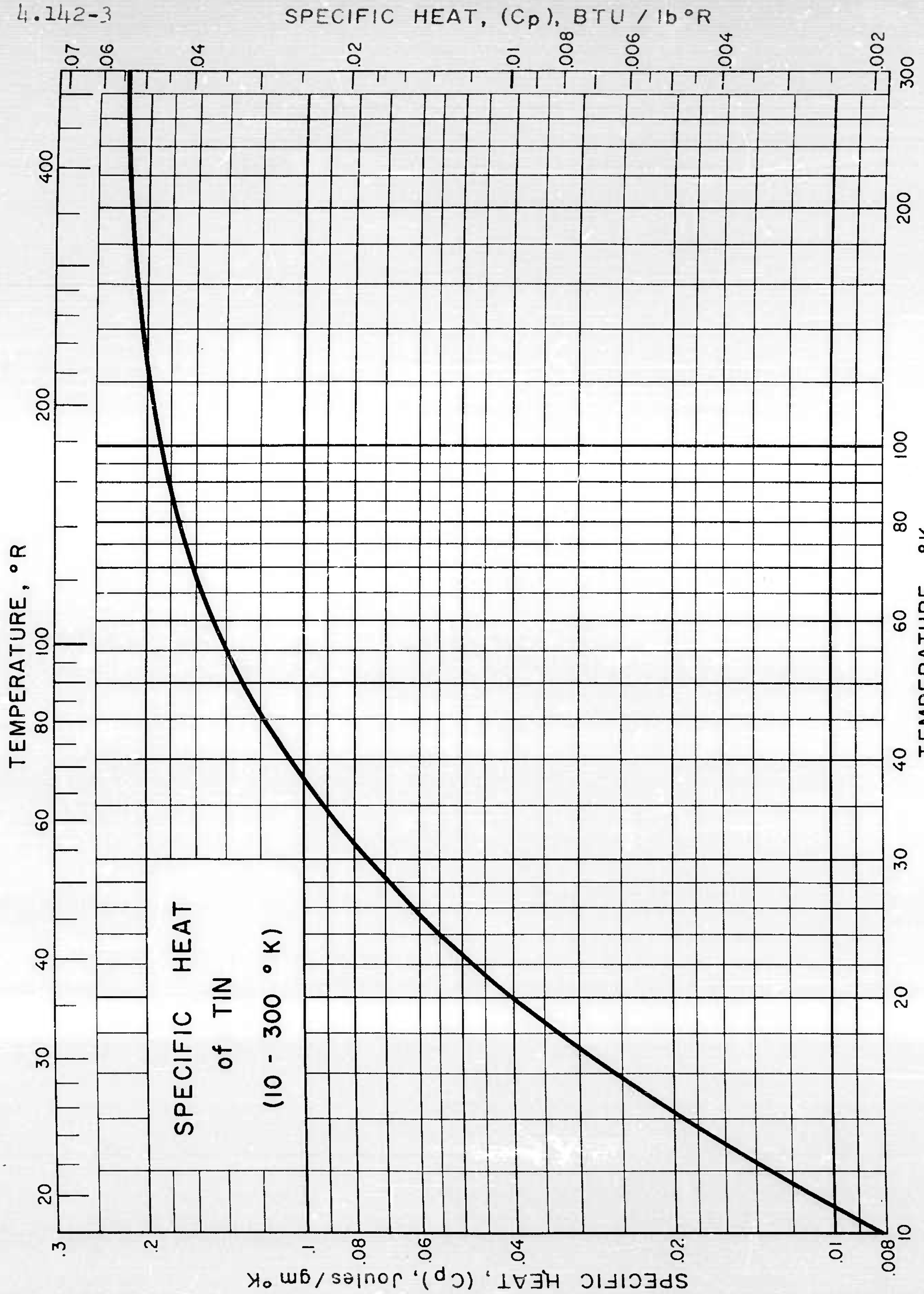
Table of Selected Values

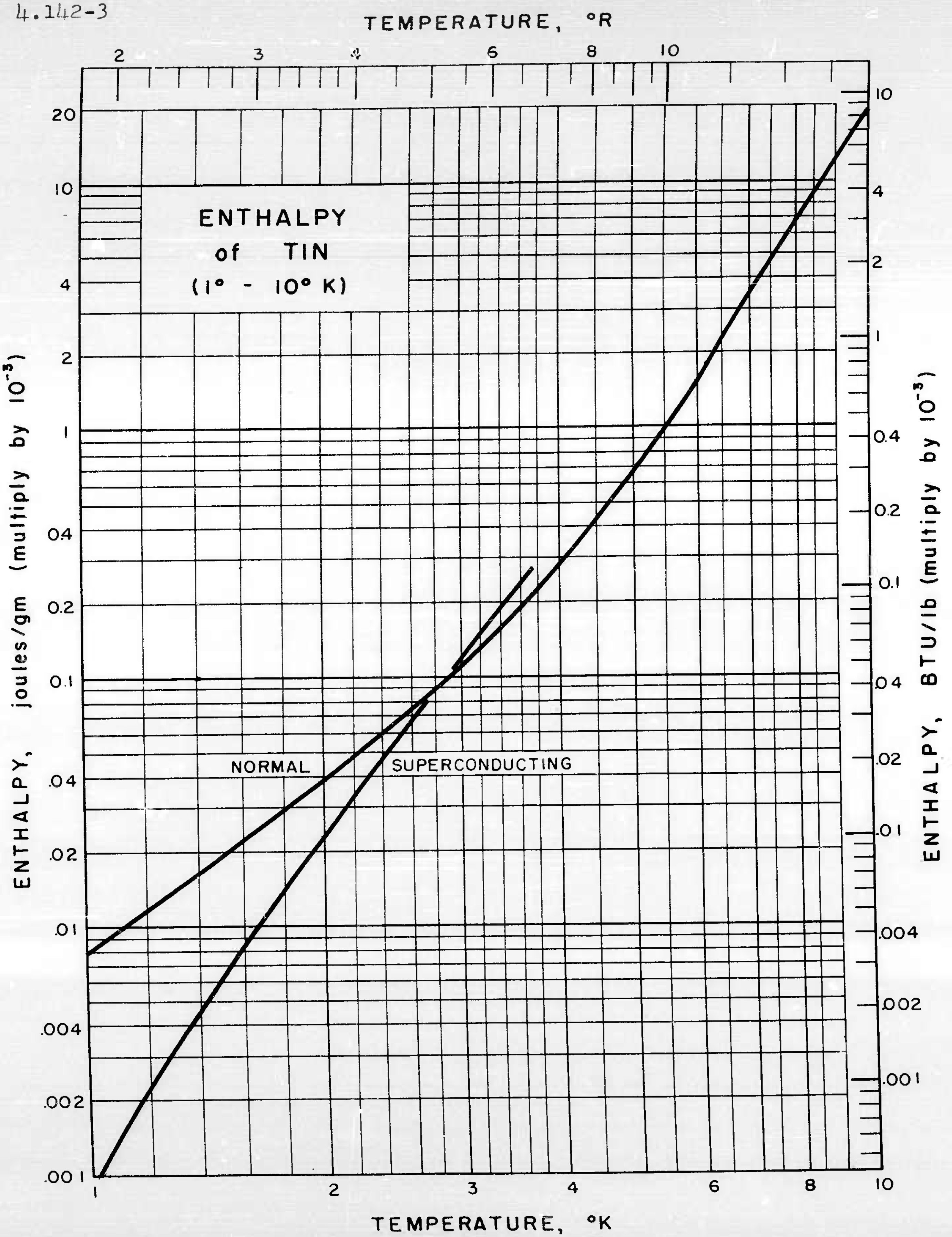
Temp.	C_p, j/gm-°K		H, j/gm		Temp.	C_p, j/gm-°K	H, j/gm
°K	Normal	Super-conducting	Normal	Super-conducting	°K	Normal	Normal
1	0.000 0170	0.000 0041	0.000 0079	0.000 0009	60	0.148	4.33
2	.000 047	.000 048	.000 0383	.000 0228	70	.162	5.88
3	.000 109	.000 151	.000 113	.000 116	80	.173	7.55
*3.72	.000 198	.000 285	.000 221	.000 270	90	.182	9.33
4	.000 245		.000 283		100	.189	11.18
5	.000 54		.000 65		120	.198	15.05
6	.001 27		.001 51		140	.204	19.1
8	.004 2		.006 8		160	.208	23.2
10	.008 1		.019 0		180	.212	27.4
15	.022 6		.093		200	.214	31.7
20	.040		.251		220	.216	36.0
25	.058		.498		240	.218	40.3
30	.076		.834		260	.220	44.7
40	.106		1.75		280	.221	49.1
50	.130		2.93		300	.222	53.6

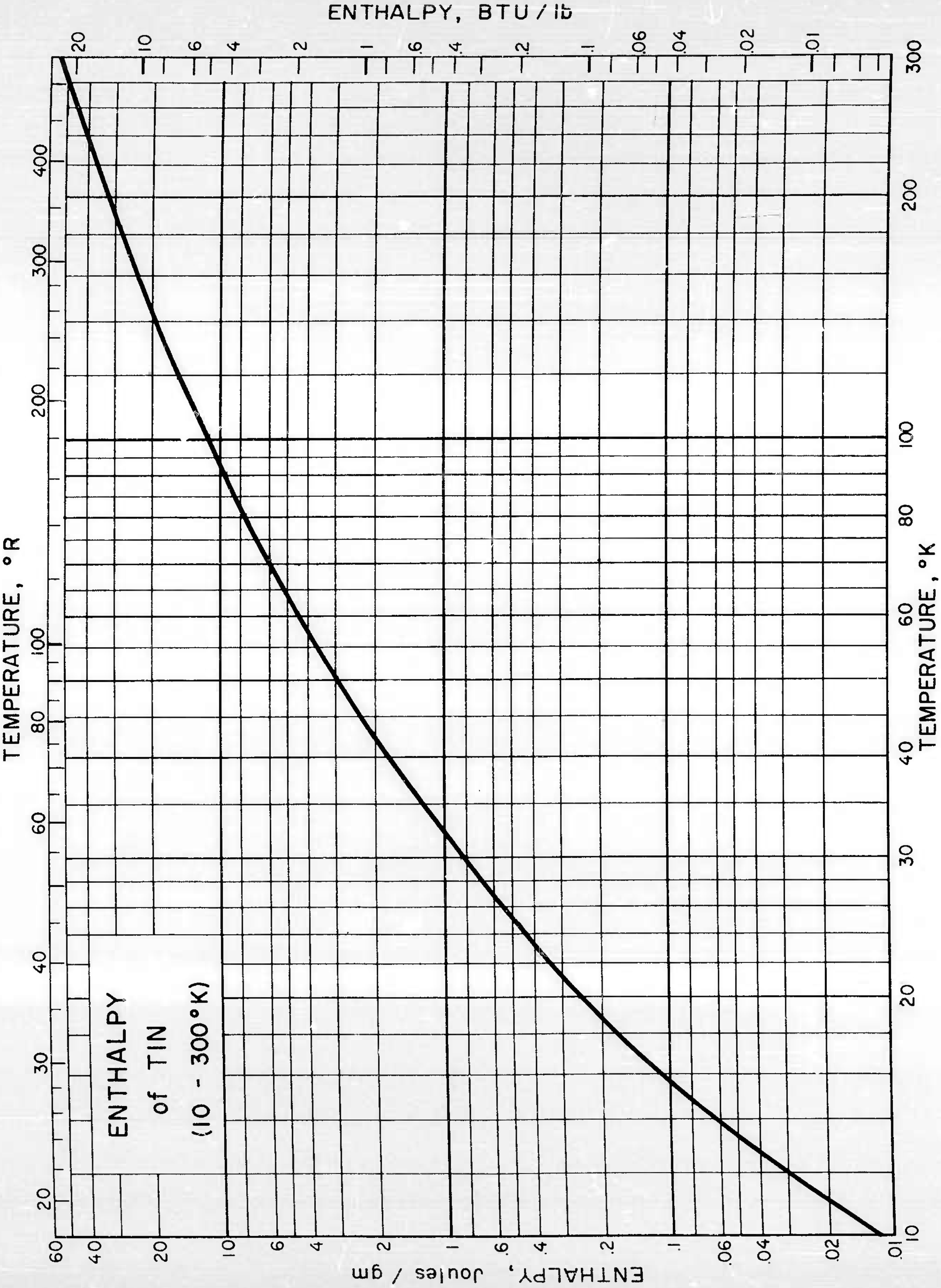
* Superconducting transition temperature

RJC Issued: 6-5-59
Revised: 5-20-60


TEMPERATURE, °R
SPECIFIC HEAT
of TIN
(1 - 10° K)
SUPERCONDUCTING
NORMAL
SPECIFIC HEAT, (Cp), Joules / gm °K (multiply by 10^-3)
SPECIFIC HEAT, (Cp), BTU/lb °R (multiply by 10^-3)
TEMPERATURE, °K


SPECIFIC HEAT of TIN (10 - 300 °K)
SPECIFIC HEAT, (Cp), BTU / lb°R
SPECIFIC HEAT, (Cp), Joules/gm °K
TEMPERATURE, °R
TEMPERATURE, °K


TEMPERATURE, °R
ENTHALPY
of TIN
(1° - 10° K)
NORMAL
SUPERCONDUCTING
ENTHALPY, joules/gm (multiply by 10^{-3})
ENTHALPY, BTU/lb (multiply by 10^{-3})
TEMPERATURE, °K


ENTHALPY
of TIN
(10 - 300°K)
ENTHALPY, BTU / lb
ENTHALPY, Joules / gm
TEMPERATURE, °R
TEMPERATURE, °K

SPECIFIC HEAT, ENTHALPY of NIOBIUM

Source of Data:

Chou, C., White, P. and Johnston, H. L., Phys. Rev. 109, 788-796 (1958)

Other References:

Brown, A., Zemansky, M. W. and Boorse, H. A., Phys. Rev. 86, 134 (1952)

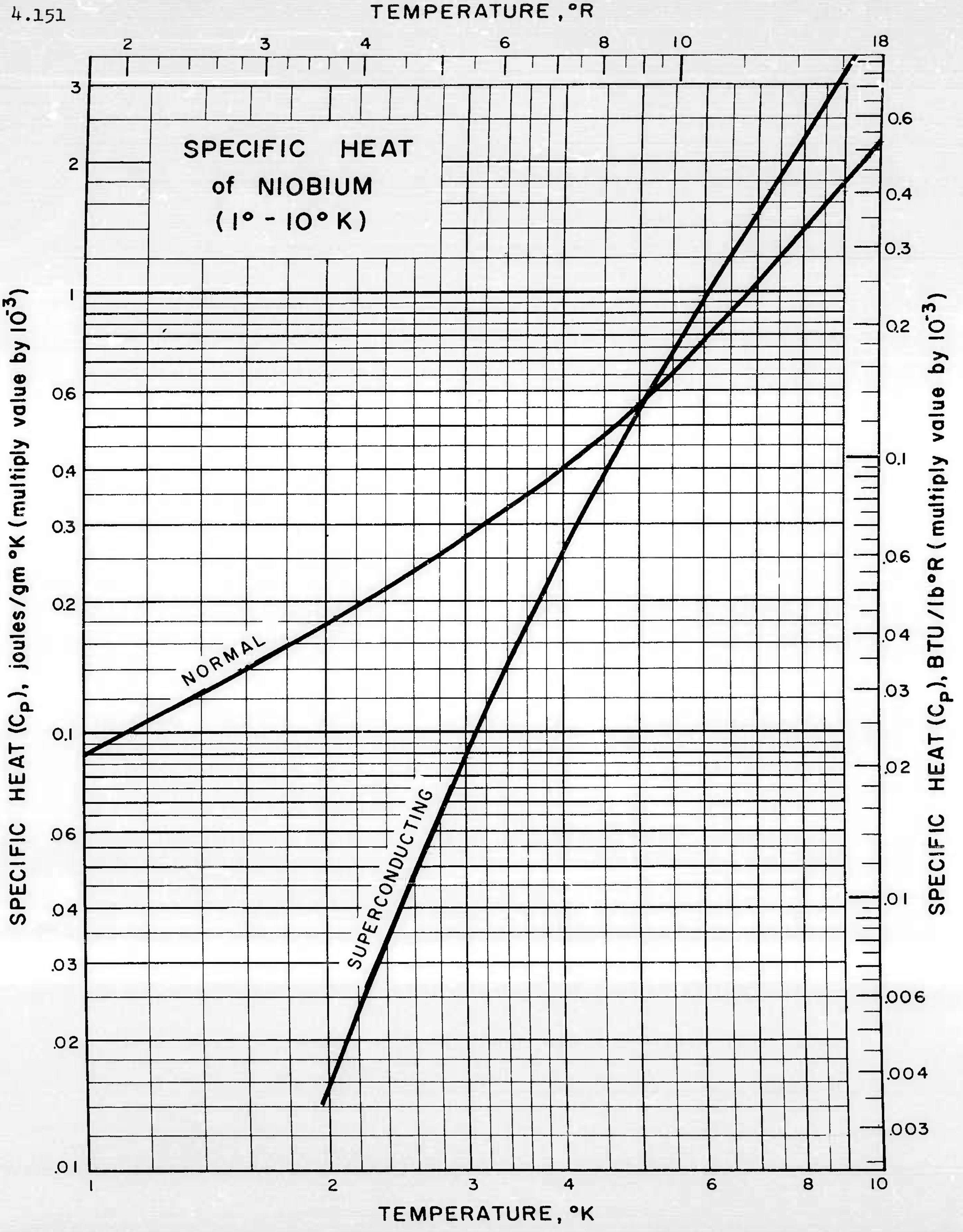
Richards, T. W. and Jackson, F. G., Z. physik. Chem. 70, 414 (1910)

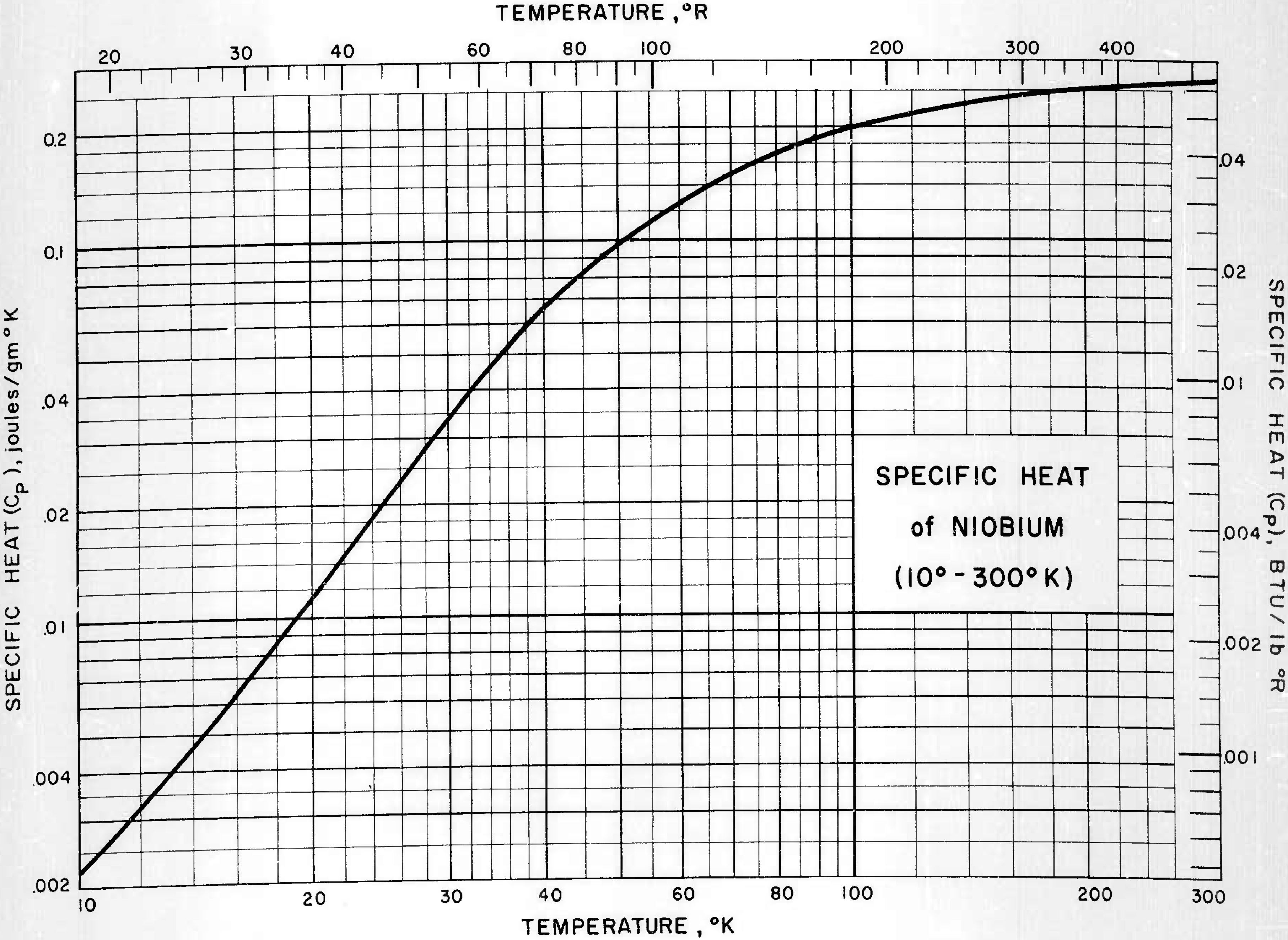
Comments:

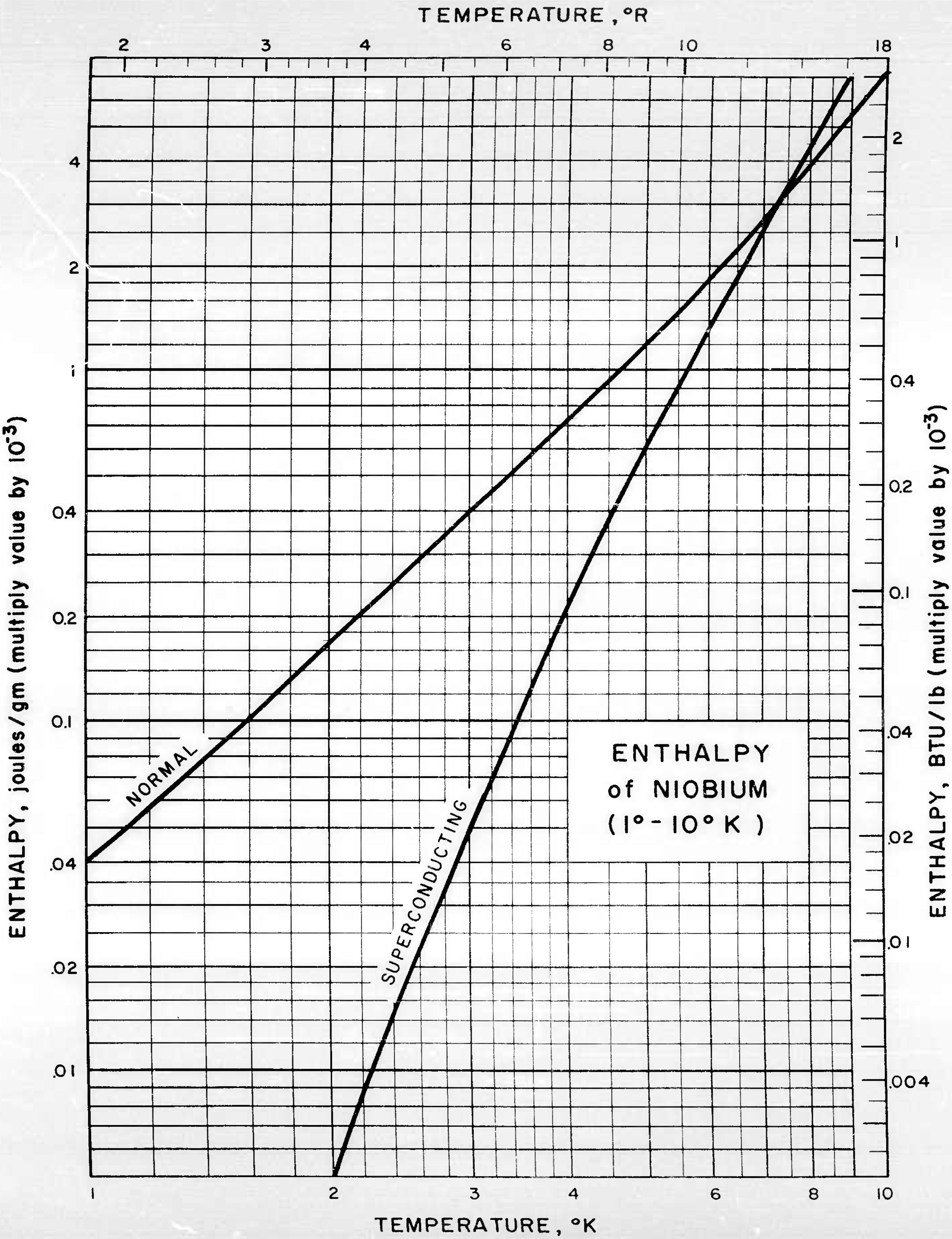
The data of Chou, White and Johnston cover the range, 1.5° to 30°K while the compilation of Kelley (1949) gives best values for room temperature and above. Between 30° and room temperature no modern experimental data are to be found. The values in this region given here are estimates. While the accuracy at 2 to 30° and at 300°K is of order 1%, the estimated values between 30° and 300°K are more uncertain and may be in error by as much as 10% in the region 40° to 100°K.

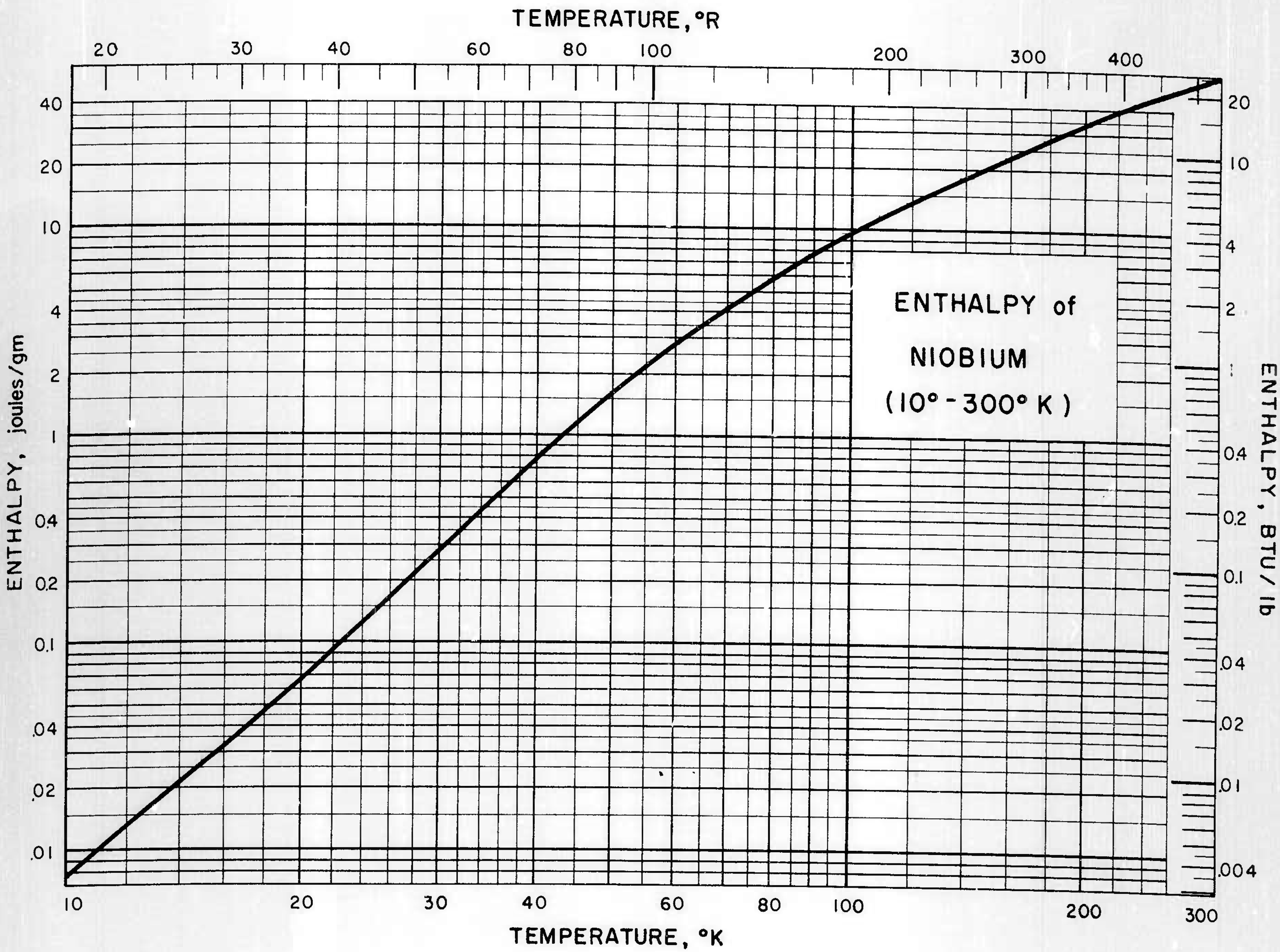
Temp.	C_p joules/gram-°K		H joules/gram		Temp.	C_p j/gm-°K	H j/gm
°K	Normal	Supercond.	Normal	Supercond.	°K	Normal	Normal
1	.09 x10^{-3}		.04 x10^{-3}		60	.127	2.76
2	.18 "	.015 x10^{-3}	.17 "	.005 x10^{-3}	70	.152	4.2
3	.28 "	.088 "	.40 "	.049 "	80	.173	5.8
4	.40 "	.27 "	.73 "	.22 "	90	.189	7.6
5	.56 "	.56 "	1.20 "	.62 "	100	.202	9.6
6	.77 "	.98 "	1.86 "	1.38 "	120	.221	13.8
7	1.02 "	1.5 "	2.75 "	2.6 "	140	.234	18.3
8	1.4 "	2.3 "	3.93 "	4.5 "	160	.243	23.1
9	1.7 "	3.2 "	5.5 "	7.2 "	180	.249	28.0
10	2.2 "		7.4 "		200	.254	33.1
15	.0055		.026		220	.258	38.2
20	.0113		.066		240	.261	43.4
25	.021		.145		260	.264	48.6
30	.035		.28		280	.266	53.9
40	.068		.80		300	.268	59.2
50	.099		1.63				

RJC/JJG Issued: 10-21-59


TEMPERATURE, °R
2
3
4
6
8
10
18
SPECIFIC HEAT
of NIOBIUM
(1° - 10° K)
NORMAL
SUPERCONDUCTING
3
2
1
0.6
0.4
0.3
0.2
0.1
.06
.04
.03
.02
.01
0.6
0.4
0.3
0.2
0.1
.06
.04
.03
.02
.01
.006
.004
.003
1
2
3
4
6
8
10
TEMPERATURE, °K
SPECIFIC HEAT (C_p), joules/gm °K (multiply value by 10^{-3})
SPECIFIC HEAT (C_p), BTU/lb °R (multiply value by 10^{-3})


TEMPERATURE, °R
20
30
40
60
80
100
200
300
400
SPECIFIC HEAT
of NIOBIUM
(10° - 300° K)
SPECIFIC HEAT (C_p), joules/gm°K
0.2
0.1
.04
.02
.01
.004
.002
SPECIFIC HEAT (C_p), BTU/lb °R
.04
.02
.01
.004
.002
.001
10
20
30
40
60
80
100
200
300
TEMPERATURE, °K


TEMPERATURE, °R
2
3
4
6
8
10
18
ENTHALPY, joules/gm (multiply value by 10^{-3})
4
2
1
0.4
0.2
0.1
.04
.02
.01
ENTHALPY, BTU/lb (multiply value by 10^{-3})
2
1
0.4
0.2
0.1
.04
.02
.01
.004
NORMAL
SUPERCONDUCTING
ENTHALPY
of NIOBIUM
(1° - 10° K)
1
2
3
4
6
8
10
TEMPERATURE, °K


TEMPERATURE, °R
20
30
40
60
80
100
200
300
400
ENTHALPY of
NIOBIUM
(10° - 300° K)
ENTHALPY, joules/gm
40
20
10
4
2
1
0.4
0.2
0.1
.04
.02
.01
ENTHALPY, BTU/ lb
20
10
4
2
1
0.4
0.2
0.1
.04
.02
.01
.004
10
20
30
40
60
80
100
200
300
TEMPERATURE, °K

SPECIFIC HEAT, ENTHALPY of TANTALUM

Sources of Data:

Kelley, K. K., J. Chem. Phys. 8, 316-22 (1940)

White, D., Chou, C. and Johnston, H. L., Phys. Rev. 109, 797-802 (1958)

Other References:

Clusius, K. and Losa, G. L., Z. Naturforsch. 10A, 939-43 (1955)

Desirant, M., Rept. Intern. Conf. Fundamental Particles and Low Temp. 2, 124 (1947)

Keesom, W. H. and Desirant, M., Physica 8, 273 (1941)

Mendlesohn, K., Nature 148, 316 (1941)

Wolcott, N. M., Conf. Physique Bases Temp., Paris (1955)

Worley, R. D., Zemansky, M. W. and Boorse, H. A., Phys. Rev. 91, 1567-8 (1953); Phys. Rev. 99, 447-58 (1955)

Comments:

For temperatures less than 4°K, the normal specific heat C_p follows the equation:

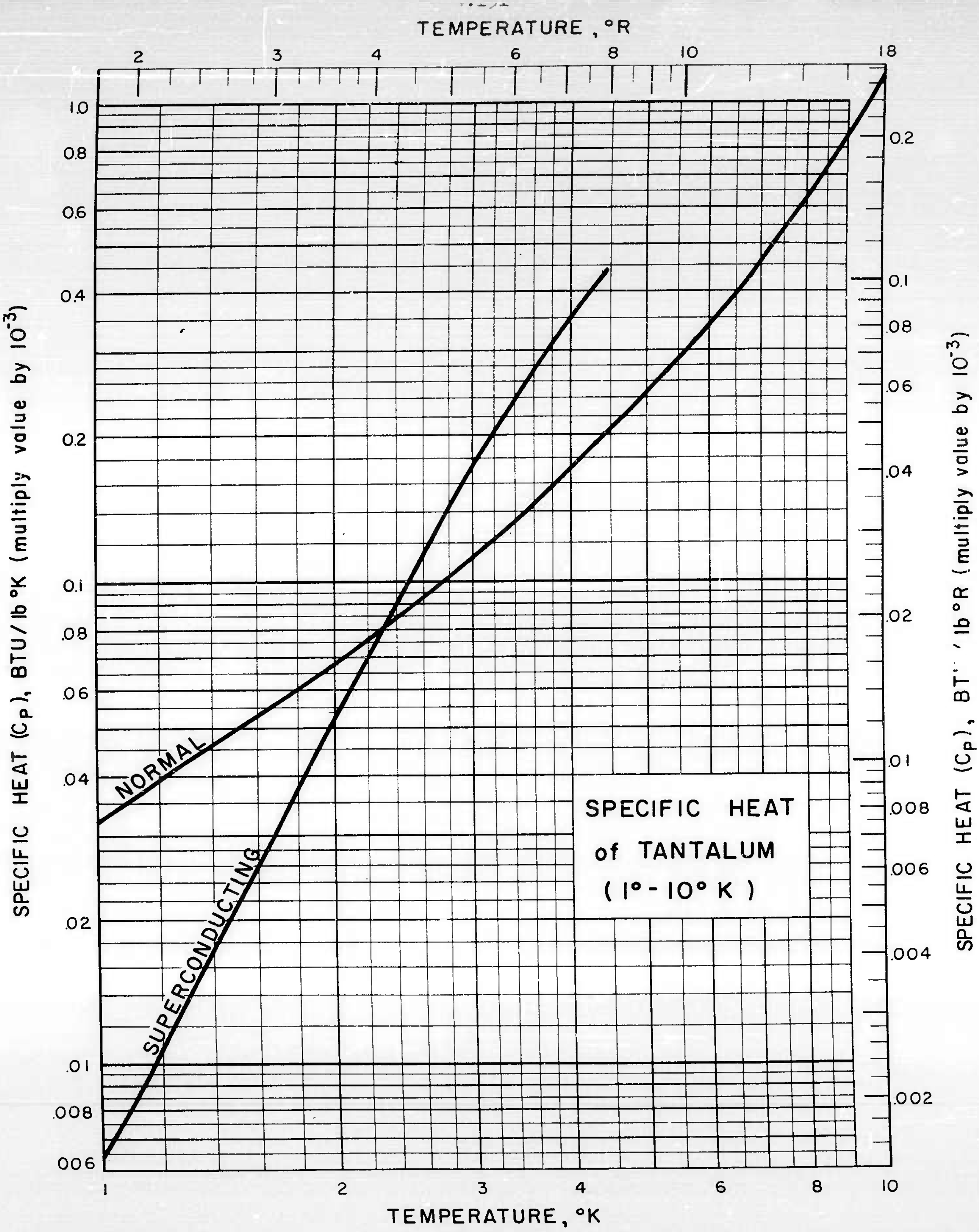
$$C_p = (31.7 \pm 0.9) \times 10^{-6} T + 10.74 \left(\frac{T}{248 \pm 6}\right)^3 \text{ j/gm-°K}$$

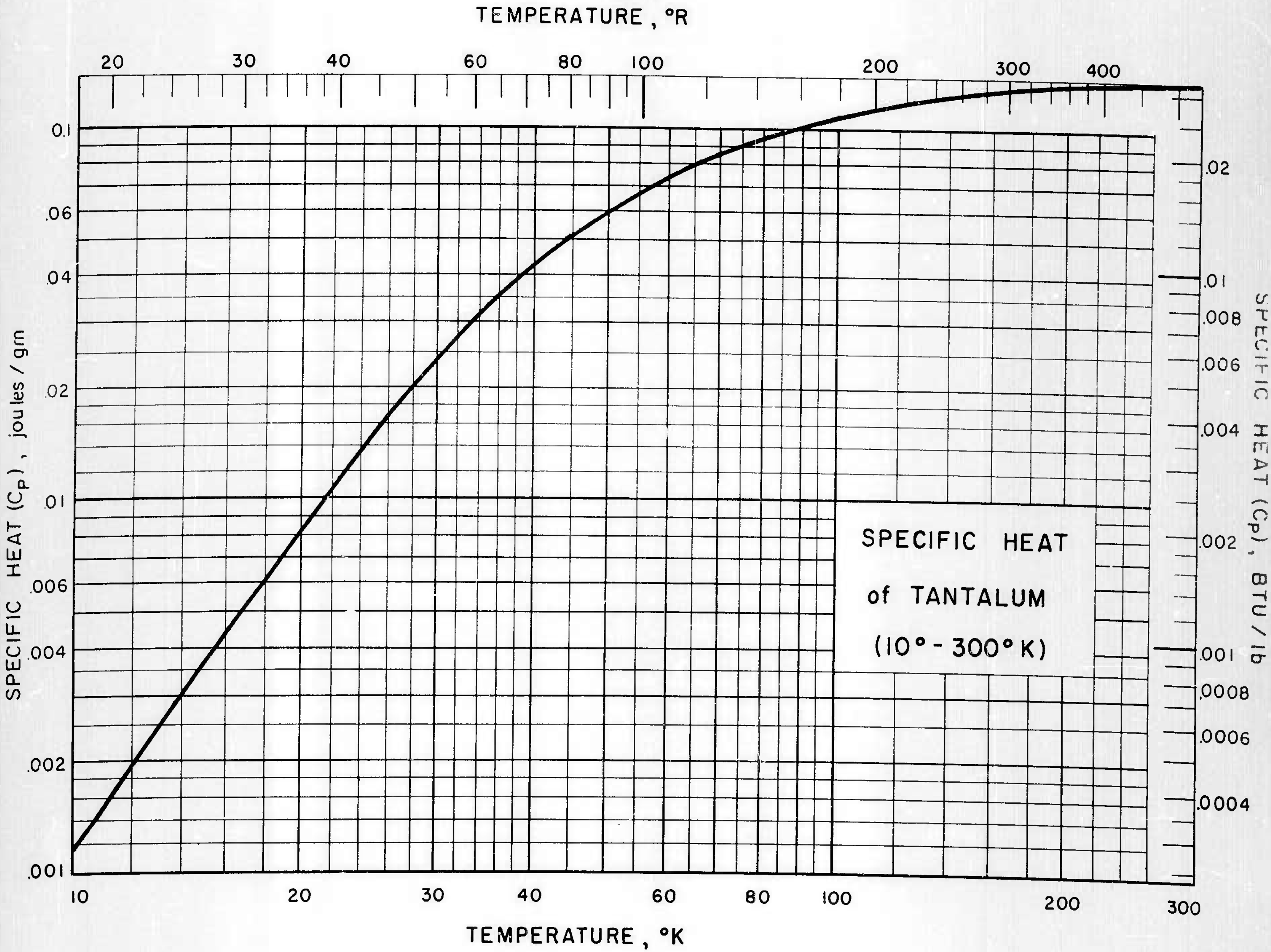
Table of Selected Values

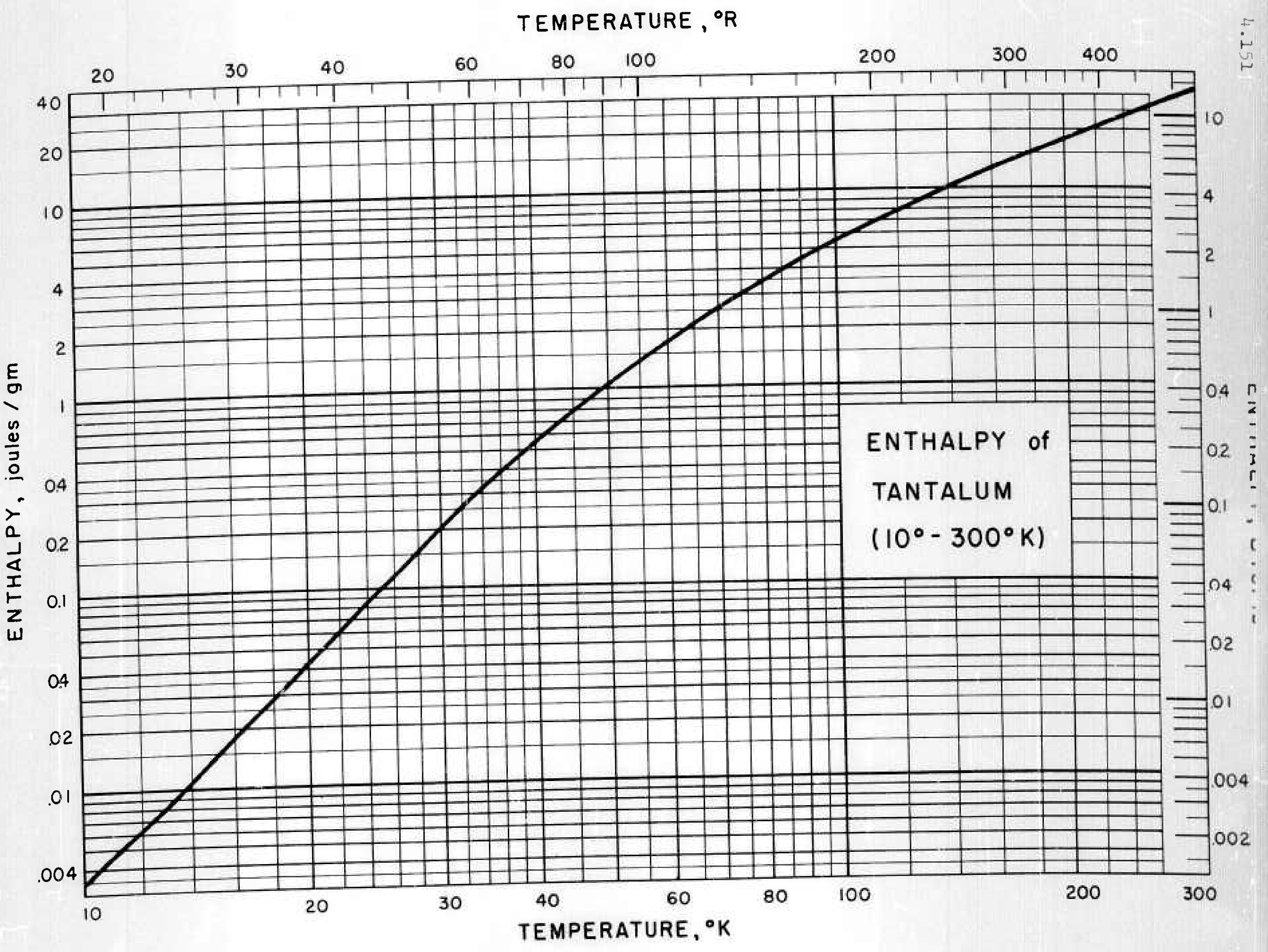
Temp. °K	C_p, j/gm-°K normal	C_p, j/gm-°K super-conducting	H, j/gm normal	H, j/gm super-conducting
1	0.000 032	0.000 0063	0.000 016	0.000 0021
2	.000 068	.000 054	.000 065	.000 026
3	.000 112	.000 178	.000 155	.000 138
4	.000 171	.000 352	.000 295	.000 400
4.39	.000 201	.000 433	.000 368	.000 553
6	.000 333		.000 776	
8	.000 648		.001 73	
10	.001 17		.003 52	
15	.003 60		.014 5	
20	.008 23		.043 2	
25	.015 3		.102	
30	.024 0		.202	
40	.043 0		.540	
50	.060 4		1.06	
60	.075 4		1.74	

Temp. °K	C_p j/gm-°K	H j/gm
70	0.0879	2.56
80	.0976	3.49
90	.105	4.50
100	.111	5.58
120	.119	7.88
140	.125	10.4
160	.128	12.9
180	.131	15.5
200	.134	18.1
220	.136	20.8
240	.137	23.6
260	.138	26.3
280	.139	29.1
300	.140	31.9

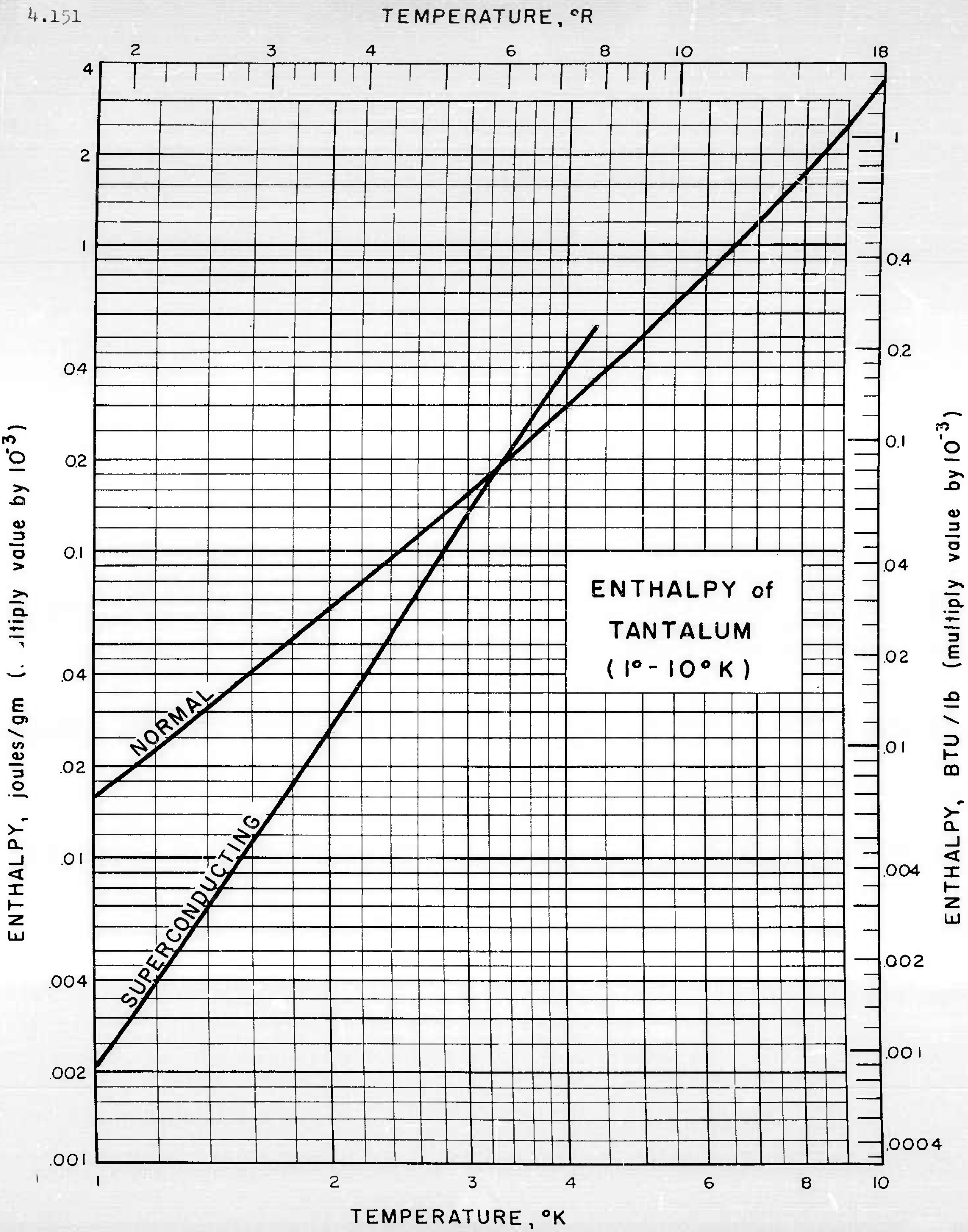
RJC/JJG/VDA Issued: 12-16-59


TEMPERATURE, °R
2
3
4
6
8
10
18
1.0
0.8
0.6
0.4
0.2
0.1
.08
.06
.04
.02
.01
.008
.006
SPECIFIC HEAT (C_p), BTU/lb °K (multiply value by 10^{-3})
0.2
0.1
.08
.06
.04
.02
.01
.008
.006
.004
.002
SPECIFIC HEAT (C_p), BT' / lb °R (multiply value by 10^{-3})
NORMAL
SUPERCONDUCTING
SPECIFIC HEAT
of TANTALUM
(1° - 10° K)
1
2
3
4
6
8
10
TEMPERATURE, °K


TEMPERATURE, °R
20
30
40
60
80
100
200
300
400
SPECIFIC HEAT (C_p), joules / gm
0.1
.06
.04
.02
.01
.006
.004
.002
.001
SPECIFIC HEAT (C_p), BTU / lb
.02
.01
.008
.006
.004
.002
.001
.0008
.0006
.0004
SPECIFIC HEAT
of TANTALUM
(10° - 300° K)
10
20
30
40
60
80
100
200
300
TEMPERATURE, °K



TEMPERATURE, °R
20
30
40
60
80
100
200
300
400
ENTHALPY, joules / gm
40
20
10
4
2
1
0.4
0.2
0.1
0.4
.02
.01
.004
ENTHALPY of
TANTALUM
(10° - 300° K)
10
4
2
1
0.4
0.2
0.1
.04
.02
.01
.004
.002
10
20
30
40
60
80
100
200
300
TEMPERATURE, °K


TEMPERATURE, °R
2
3
4
6
8
10
18
4
2
1
0.4
0.2
0.1
.04
.02
.01
.004
.002
.001
1
0.4
0.2
0.1
.04
.02
.01
.004
.002
.001
.0004
ENTHALPY, joules/gm (multiply value by 10^{-3})
ENTHALPY, BTU/lb (multiply value by 10^{-3})
NORMAL
SUPERCONDUCTING
ENTHALPY of
TANTALUM
(1° - 10° K)
1
2
3
4
6
8
10
TEMPERATURE, °K

SPECIFIC HEAT, ENTHALPY of BISMUTH

Sources of Data:

Anderson, C. T., J. Am. Chem. Soc. 52, 2720 (1930)

Armstrong, L. D. and Grayson-Smith, H., Can. J. Research A27, 9 (1949)

Bronson, H. L. and MacHattie, L. E., Can. J. Research A16, 177 (1938)

Kalinkina, I. V. and Strelkov, P. G., Zhur. Eksptl. i Teoret. Fiz. 34, 616-21 (1958)

Keesom, P. H. and Pearlman, N., Phys. Rev. 96, 897-902 (1954)

Keesom, W. H. and Van Den Ende, J. N., Communs. Phys. Lab. Univ. Leiden No. 213c (1931)

Other References:

Ramanathan, K. G. and Srinivasan, T. M., Phil. Mag. 46, 338 (1955)

Comments:

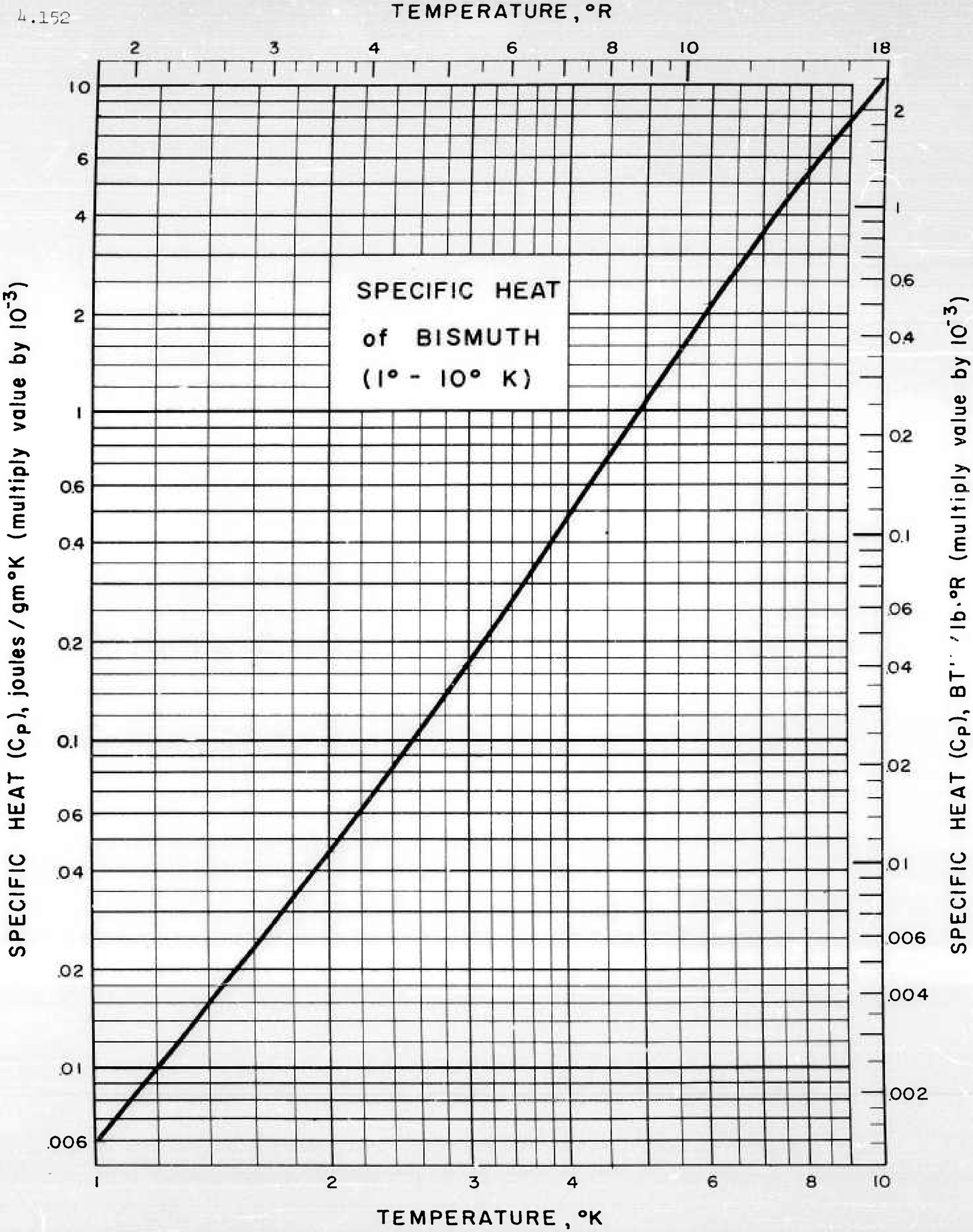
In the temperature range from 0° to 2°K, the specific heat C_p follows the equation:

$$C_p = (3.2 \pm 0.2) \times 10^{-7} T + 9.303 \left(\frac{T}{118 \pm 1} \right)^3 \text{ j/gm-°K}$$

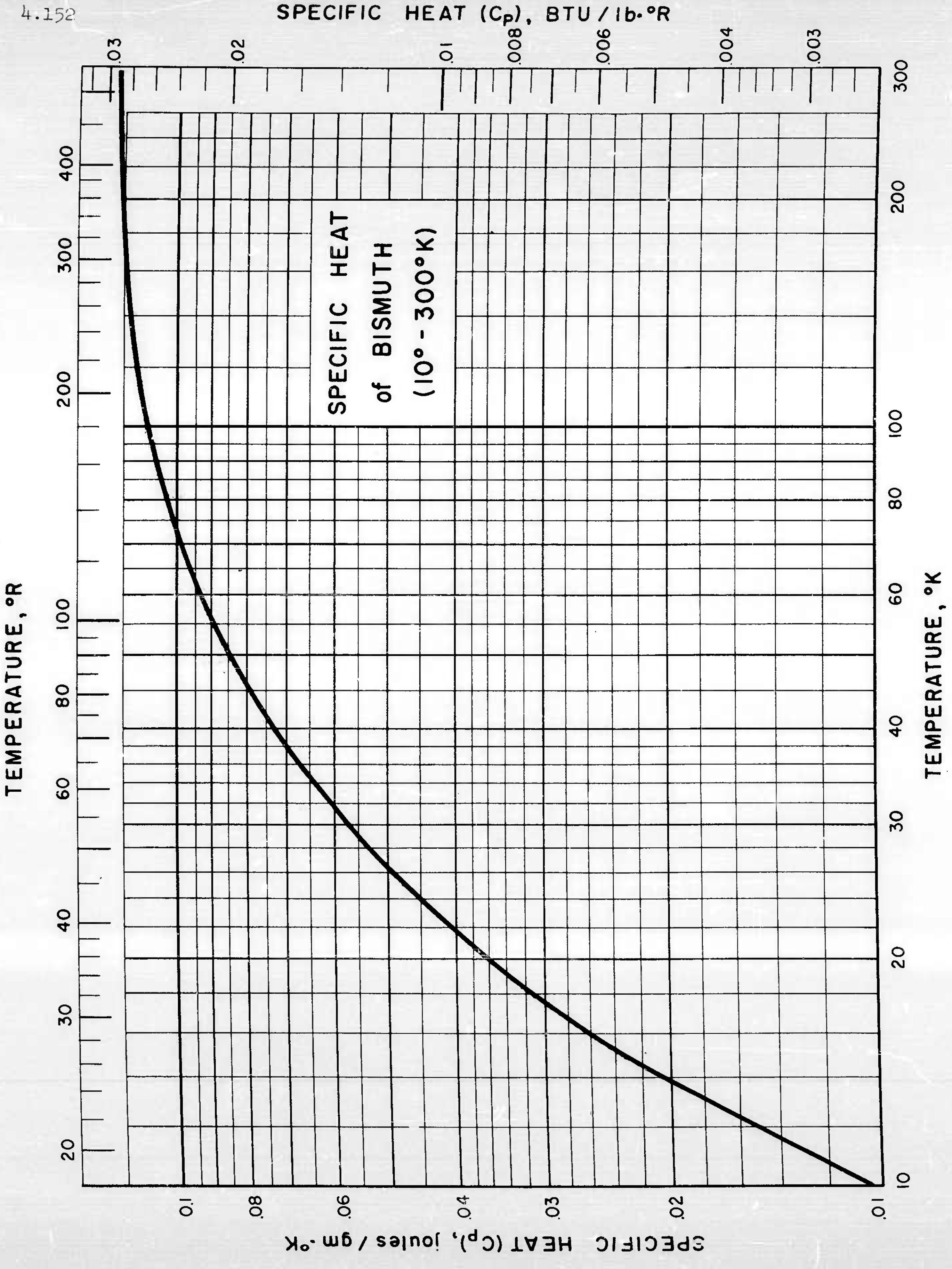
Table of Selected Values

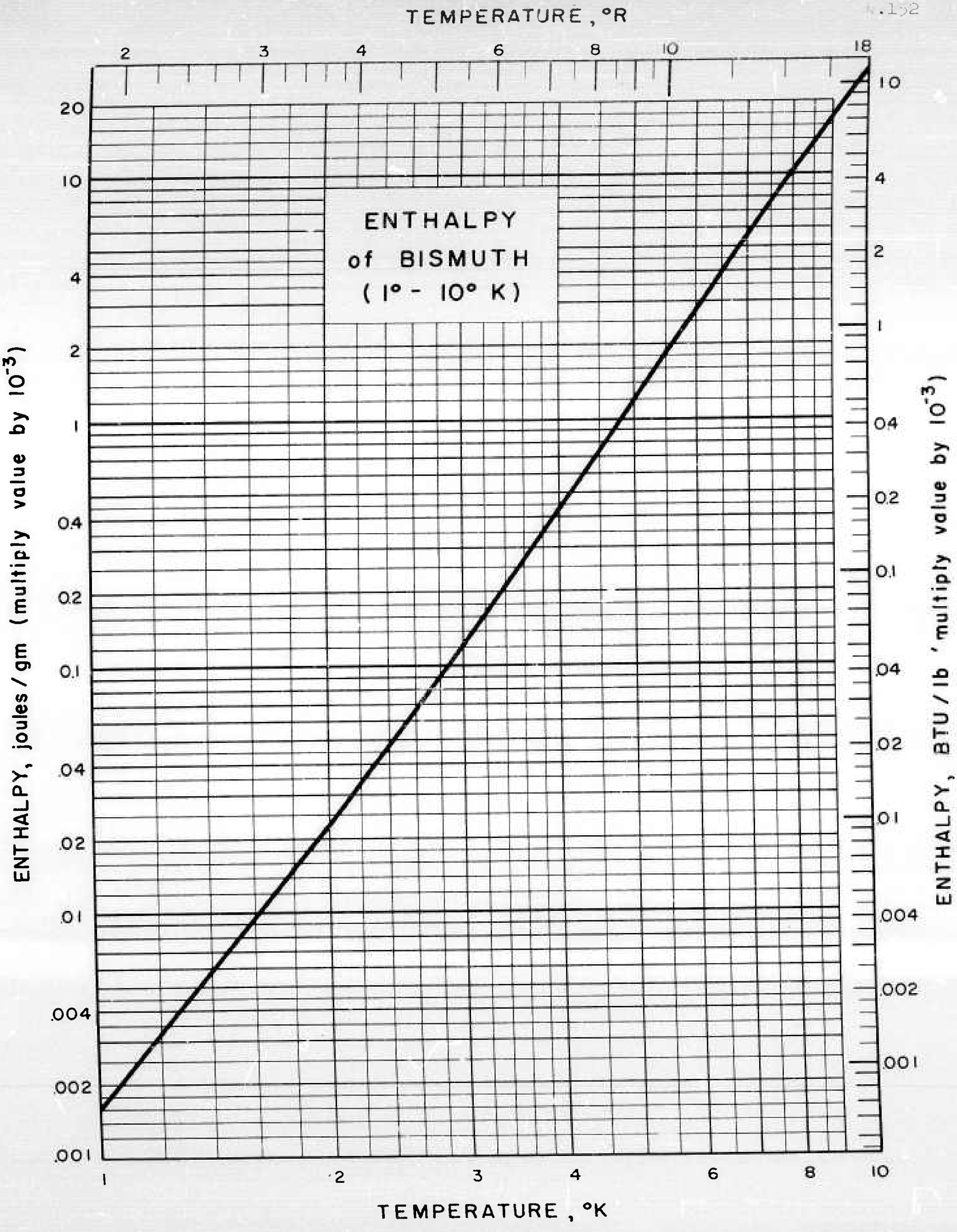
Temp. °K	C_p j/gm-°K	H j/gm	Temp. °K	C_p j/gm-°K	H j/gm
1	0.000 00598	0.000 00158	70	0.100	4.03
2	.000 0461	.000 0233	80	.105	5.05
3	.000 170	.000 123	90	.108	6.12
4	.000 493	.000 432	100	.111	7.21
6	.002 14	.002 88	120	.114	9.45
8	.005 47	.010 2	140	.116	11.8
10	.010 4	.025 9	160	.118	14.1
15	.023 8	.111	180	.119	16.5
20	.036 3	.262	200	.120	18.9
25	.047 7	.472	220	.121	21.3
30	.057 2	.734	240	.122	23.7
40	.072 7	1.38	260	.122	26.2
50	.084 6	2.17	280	.123	28.6
60	.093 5	3.06	300	.124	31.1

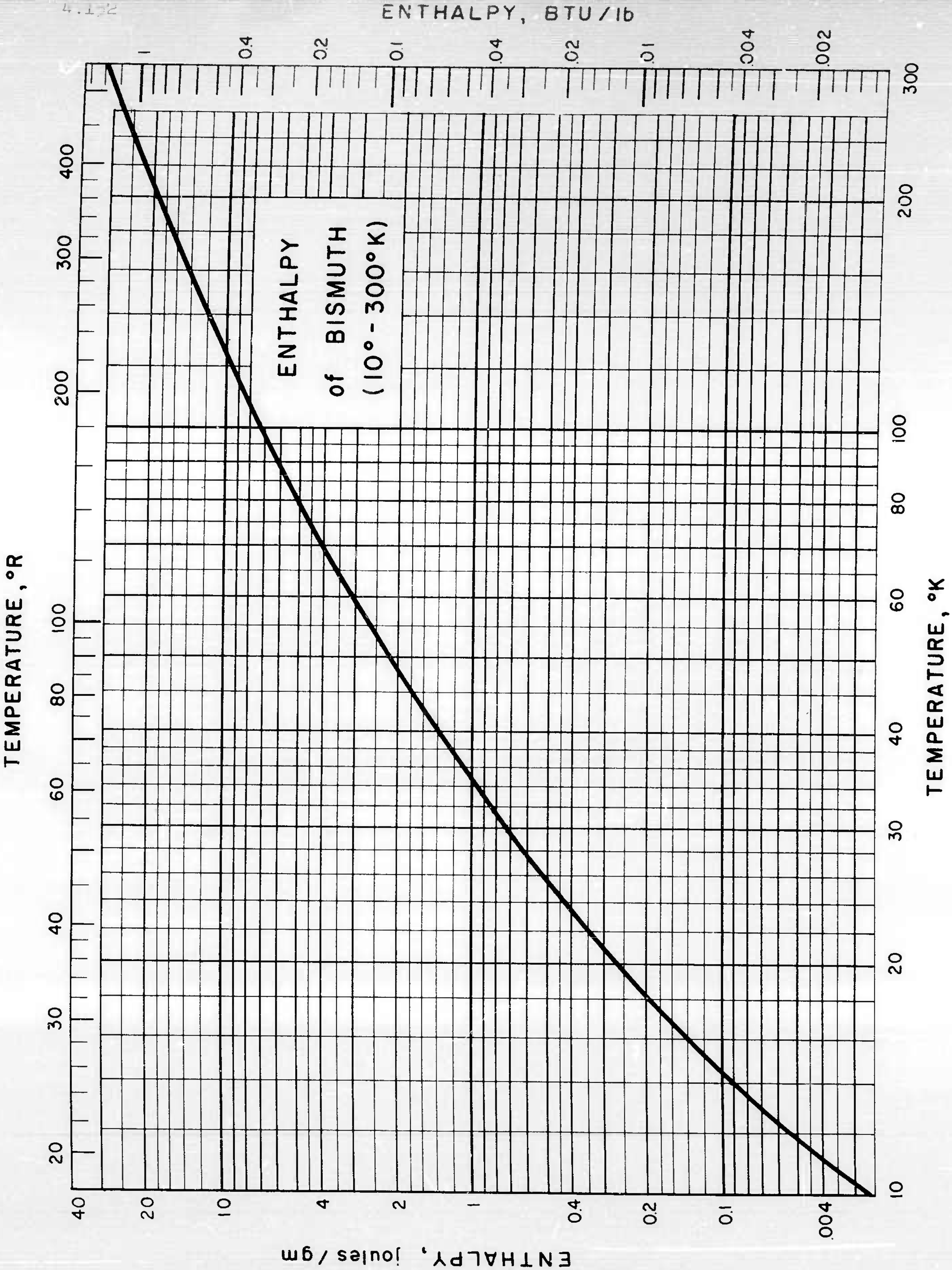
JJG/JRC Issued: 10-19-59
Revised: 5-20-60



TEMPERATURE, °R
2
3
4
6
8
10
18
SPECIFIC HEAT
of BISMUTH
(1° - 10° K)
SPECIFIC HEAT (C_p), joules / gm°K (multiply value by 10^{-3})
10
6
4
2
1
0.6
0.4
0.2
0.1
.06
.04
.02
.01
.006
SPECIFIC HEAT (C_p), BT'' / lb·°R (multiply value by 10^{-3})
2
1
0.6
0.4
0.2
0.1
.06
.04
.02
.01
.006
.004
.002
TEMPERATURE, °K
1
2
3
4
6
8
10


SPECIFIC HEAT (Cp), BTU / lb·°R
.03
.02
.01
.008
.006
.004
.003
SPECIFIC HEAT
of BISMUTH
(10° - 300°K)
TEMPERATURE, °R
400
300
200
100
80
60
40
30
20
TEMPERATURE, °K
300
200
100
80
60
40
30
20
10
SPECIFIC HEAT (Cp), joules / gm-°K
0.1
.08
.06
.04
.03
.02
0.1


TEMPERATURE, °R
2
3
4
6
8
10
18
ENTHALPY
of BISMUTH
(1° - 10° K)
20
10
4
2
1
0.4
0.2
0.1
.04
.02
.01
.004
.002
.001
ENTHALPY, joules / gm (multiply value by 10^{-3})
1.0
4
2
1
.04
.02
.01
.04
.02
.01
.004
.002
.001
ENTHALPY, BTU / lb (multiply value by 10^{-3})
1
2
3
4
6
8
10
TEMPERATURE, °K



ENTHALPY, BTU/lb
1
0.4
0.2
0.1
.04
.02
.01
.004
.002
ENTHALPY
of BISMUTH
(10° - 300°K)
TEMPERATURE, °R
400
300
200
100
80
60
40
30
20
TEMPERATURE, °K
300
200
100
80
60
40
30
20
10
ENTHALPY, joules/gm
40
20
10
4
2
1
0.4
0.2
0.1
.004

SPECIFIC HEAT, ENTHALPY of CHROMIUM

Sources of Data:

Anderson, C. T., J. Am. Chem. Soc. 59, 488-91 (1937)

Rayne, J. A. and Kemp, W. R. G., Phil. Mag. (8) 1, 918-25 (1956)

Wolcott, N. M., Conf. Physique Basses Temp., Paris (1955)

Other References:

Adler, F. W., Ann. Physik. Beiblätter 27, 330 (1903)

Estermann, I., Friedberg, S. A. and Goldman, J. E., Phys. Rev. 87, 582-8 (1952)

Forch, C. and Nordmeyer, P., Ann. Physik. (4) 20, 423 (1906)

Richards, T. W. and Jackson, F. G., Z. physik. Chem. 70, 414 (1910)

Simon, F. and Ruhemann, M., Z. physik. Chem. 129, 321 (1927)

Weertman, J. R., Burk, D. and Goldman, J. E., Phys. Rev. 86, 628 (1952)

Friedberg, S. A., Estermann, I. and Goldman, J. E., Phys. Rev. 85, 375 (1952)

Comments:

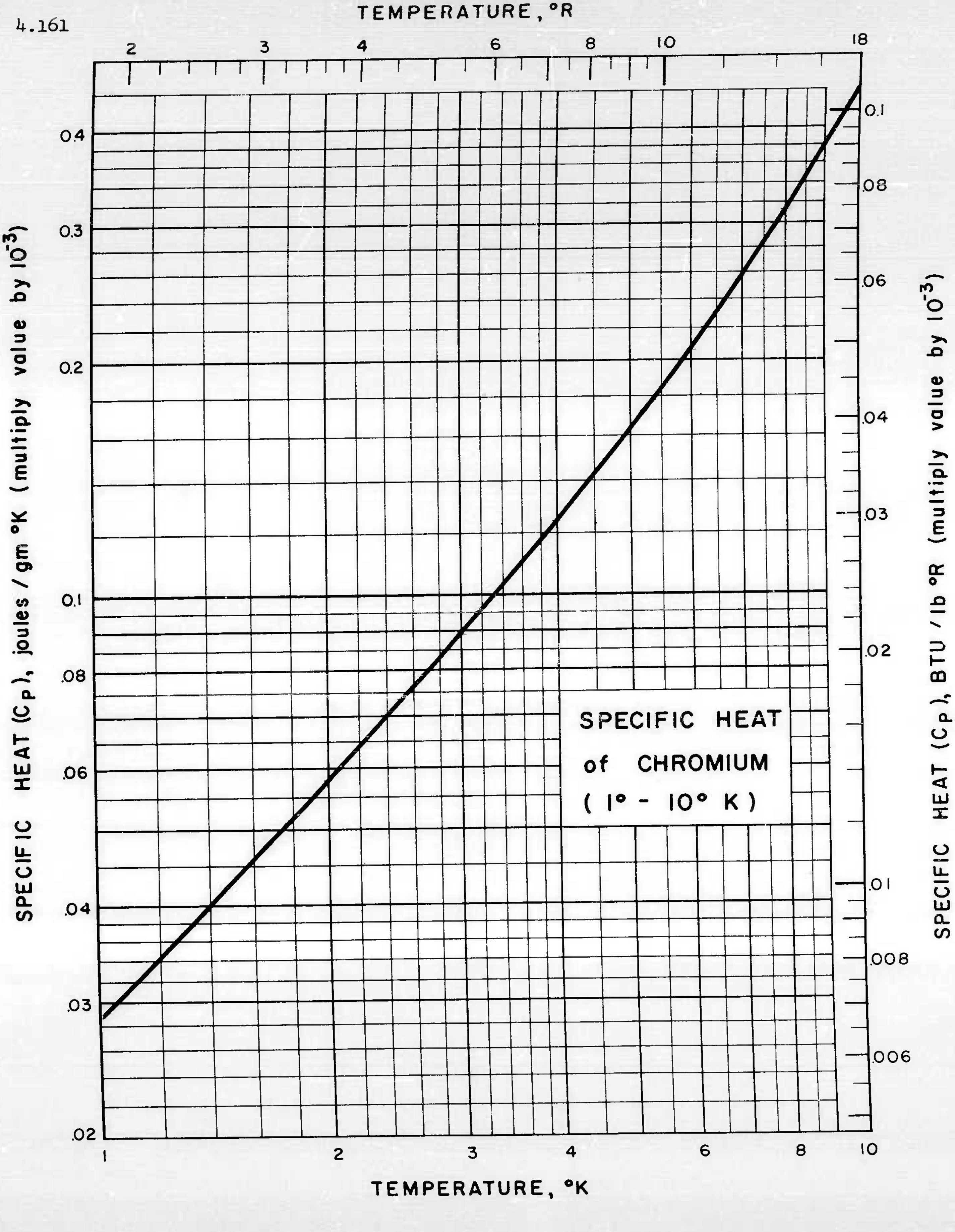
For temperatures from 0° to 4°K, the specific heat Cp follows the equation:

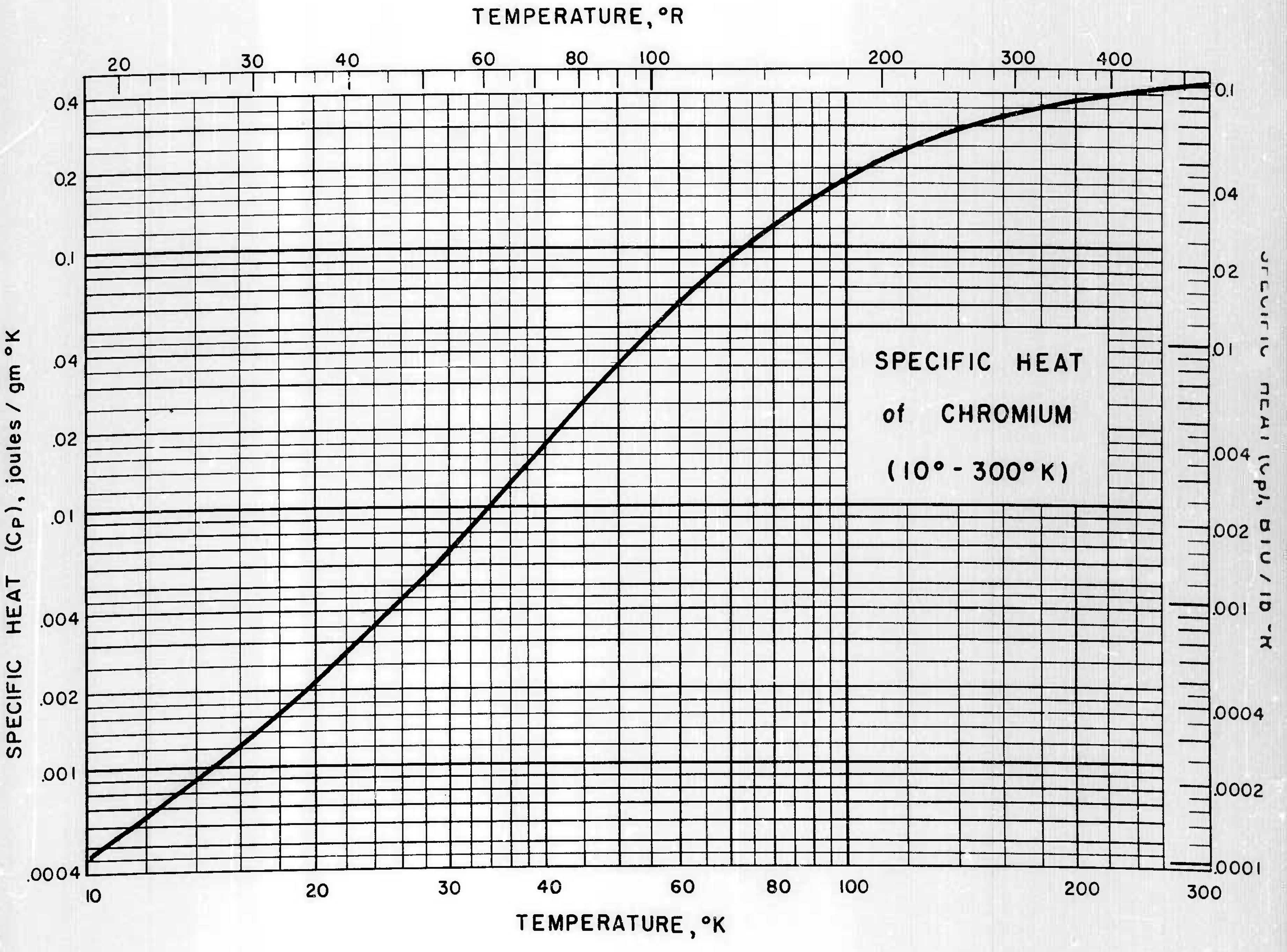
$$C_p = (2.83 \pm 0.12) \times 10^{-5} T + 37.39 \left(\frac{T}{610 \pm 30}\right)^3 \text{ j/gm-°K}$$

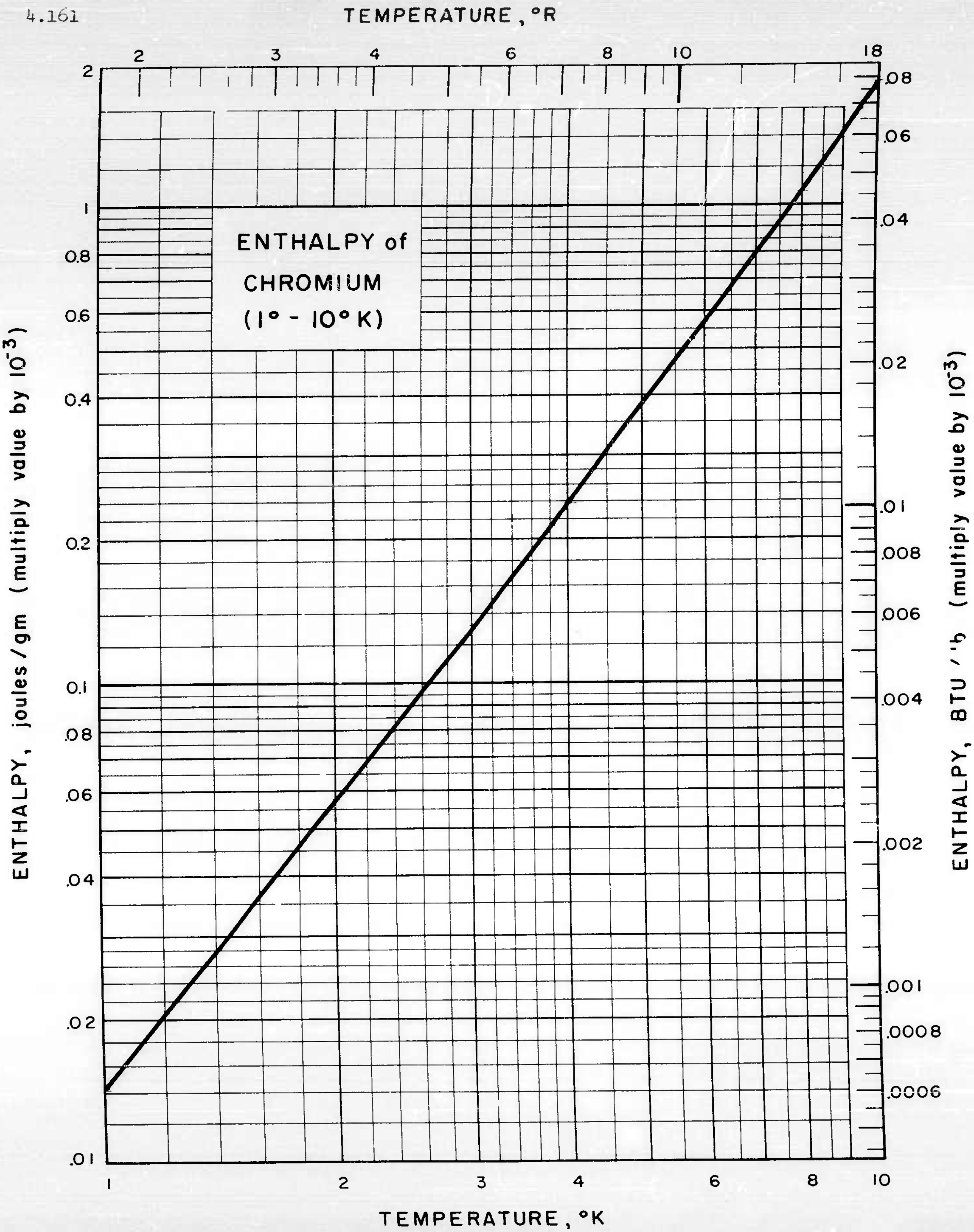
Table of Selected Values

Temp. °K	C_p j/gm-°K	H j/gm	Temp. °K	C_p j/gm-°K	H j/gm
1	0.000 0285	0.000 0142	70	0.093	1.68
2	.000 058	.000 0573	80	.127	2.77
3	.000 089	.000 131	90	.161	4.21
4	.000 124	.000 237	100	.193	5.98
6	.000 206	.000 567	120	.249	10.4
8	.000 312	.001 07	140	.296	15.9
10	.000 451	.001 82	160	.332	22.2
15	.001 02	.005 28	180	.361	29.1
20	.002 10	.012 8	200	.385	36.6
25	.003 92	.027 4	220	.404	44.5
30	.006 83	.053 2	240	.419	52.7
40	.017 1	.163	260	.431	61.2
50	.035 8	.421	280	.441	70.0
60	.062 1	.904	300	.450	78.9

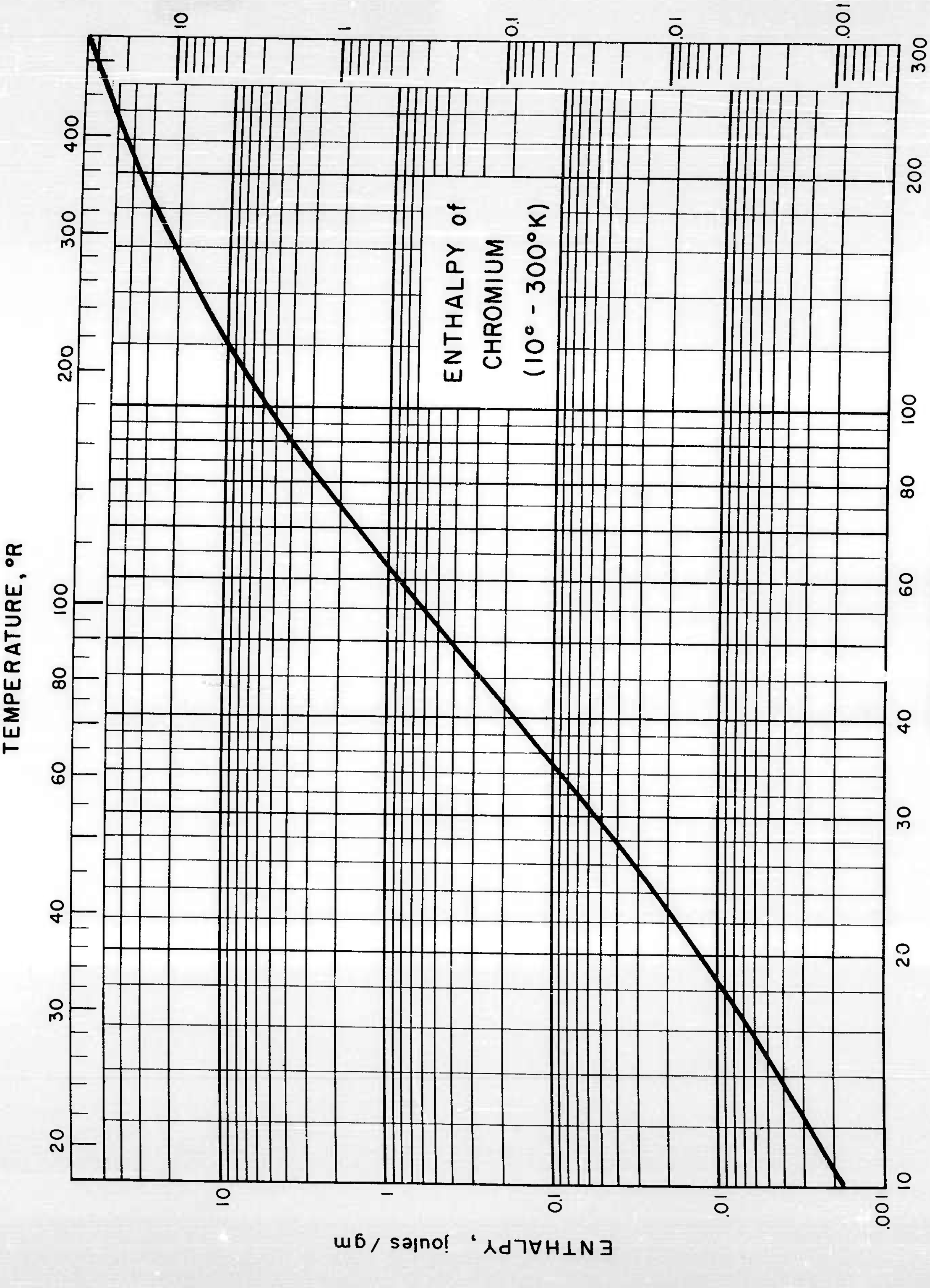
RJC Issued: 12-18-59
Revised: 5-20-60


TEMPERATURE, °R
2
3
4
6
8
10
18
0.4
0.3
0.2
0.1
.08
.06
.04
.03
.02
0.1
.08
.06
.04
.03
.02
.01
.008
.006
SPECIFIC HEAT (C_p), joules / gm °K (multiply value by 10^{-3})
SPECIFIC HEAT (C_p), BTU / lb °R (multiply value by 10^{-3})
SPECIFIC HEAT
of CHROMIUM
(1° - 10° K)
1
2
3
4
6
8
10
TEMPERATURE, °K


TEMPERATURE, °R
20
30
40
60
80
100
200
300
400
SPECIFIC HEAT
of CHROMIUM
(10° - 300°K)
SPECIFIC HEAT (C_p), joules / gm °K
0.4
0.2
0.1
.04
.02
.01
.004
.002
.001
.0004
SPECIFIC HEAT (C_p), BTU / lb °R
0.1
.04
.02
.01
.004
.002
.001
.0004
.0002
.0001
TEMPERATURE, °K
10
20
30
40
60
80
100
200
300



TEMPERATURE, °R
2
3
4
6
8
10
18
ENTHALPY of
CHROMIUM
(1° - 10° K)
ENTHALPY, joules/gm (multiply value by 10^{-3})
2
1
0.8
0.6
0.4
0.2
0.1
.08
.06
.04
.02
.01
ENTHALPY, BTU/lb (multiply value by 10^{-3})
.08
.06
.04
.02
.01
.008
.006
.004
.002
.001
.0008
.0006
1
2
3
4
6
8
10
TEMPERATURE, °K


ENTHALPY, BTU / lb
10
1
.1
.01
.001
ENTHALPY of
CHROMIUM
(10° - 300°K)
TEMPERATURE, °R
20
30
40
60
80
100
200
300
400
TEMPERATURE, °K
10
20
30
40
60
80
100
200
300
ENTHALPY, joules / gm
10
1
.1
.01
.001

SPECIFIC HEAT, ENTHALPY of MOLYBDENUM

Sources of Data:

Horowitz, M. and Daunt, J. G., Phys. Rev. 91, 1099-1106 (1953)

Rayne, J. A., Phys. Rev. 95, 1428-34 (1954)

Simon, F. and Zeidler, W., Z. physik. Chem. 123, 383-404 (1926)

Other References:

Cooper, D. and Longstroeth, G., Phys. Rev. 33, 243-8 (1929)

Comments:

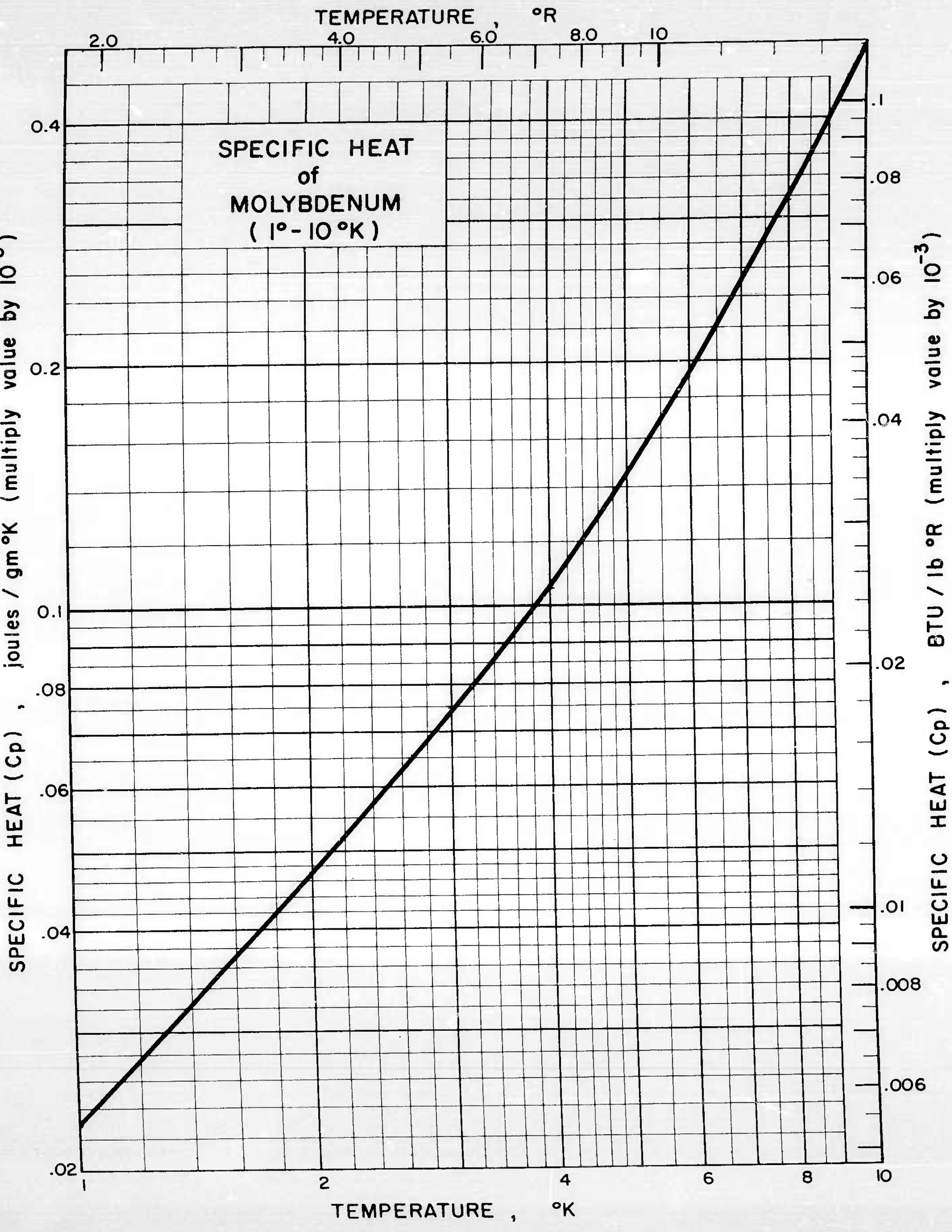
For the temperature range from 0° to 4°K, the specific heat C_p follows the equation:

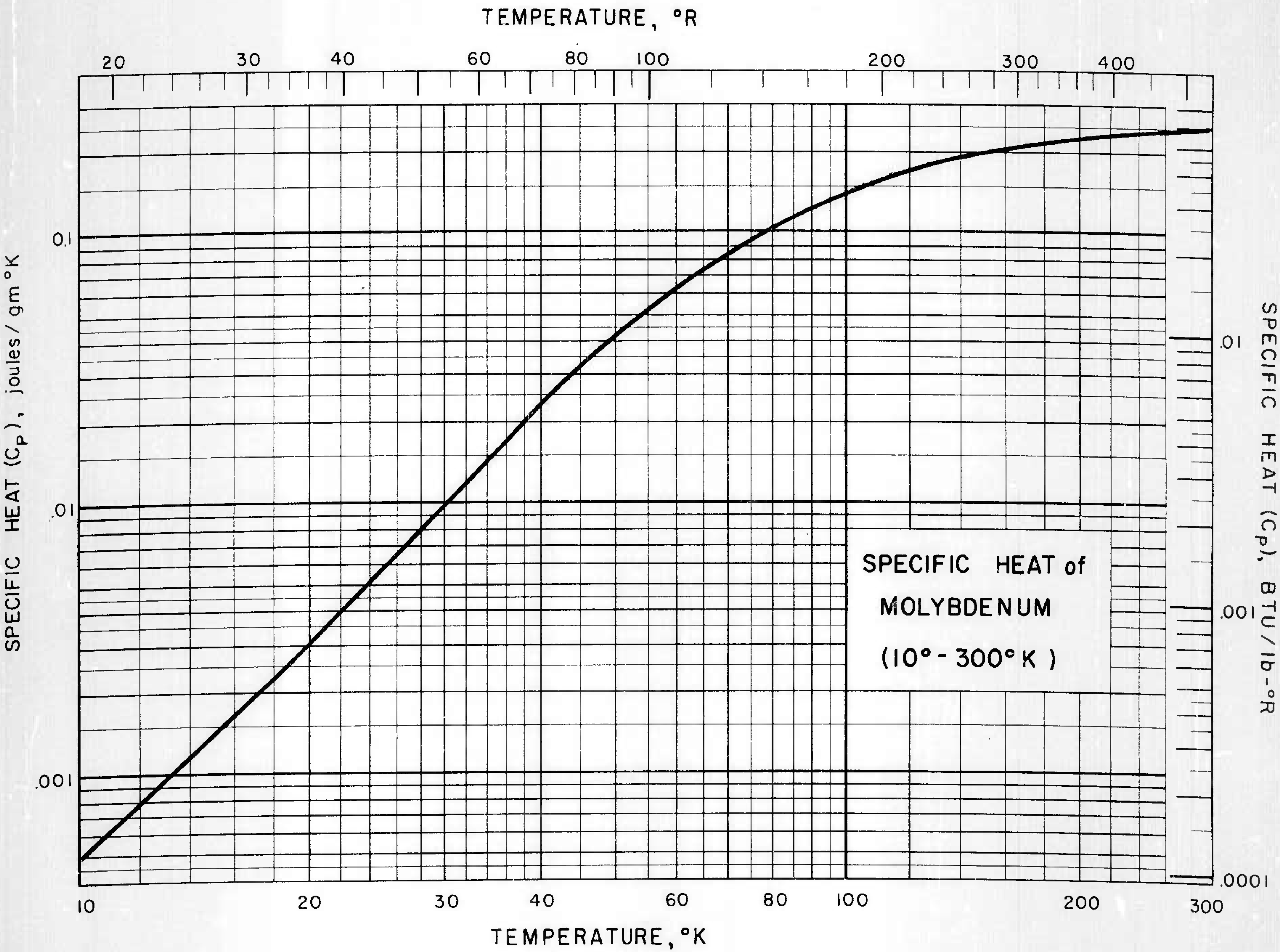
$$C_p = (2.27 \pm 0.1) \times 10^{-5} T + 20.26 \left(\frac{T}{430 \pm 15} \right)^3 \text{ j/gm-°K}$$

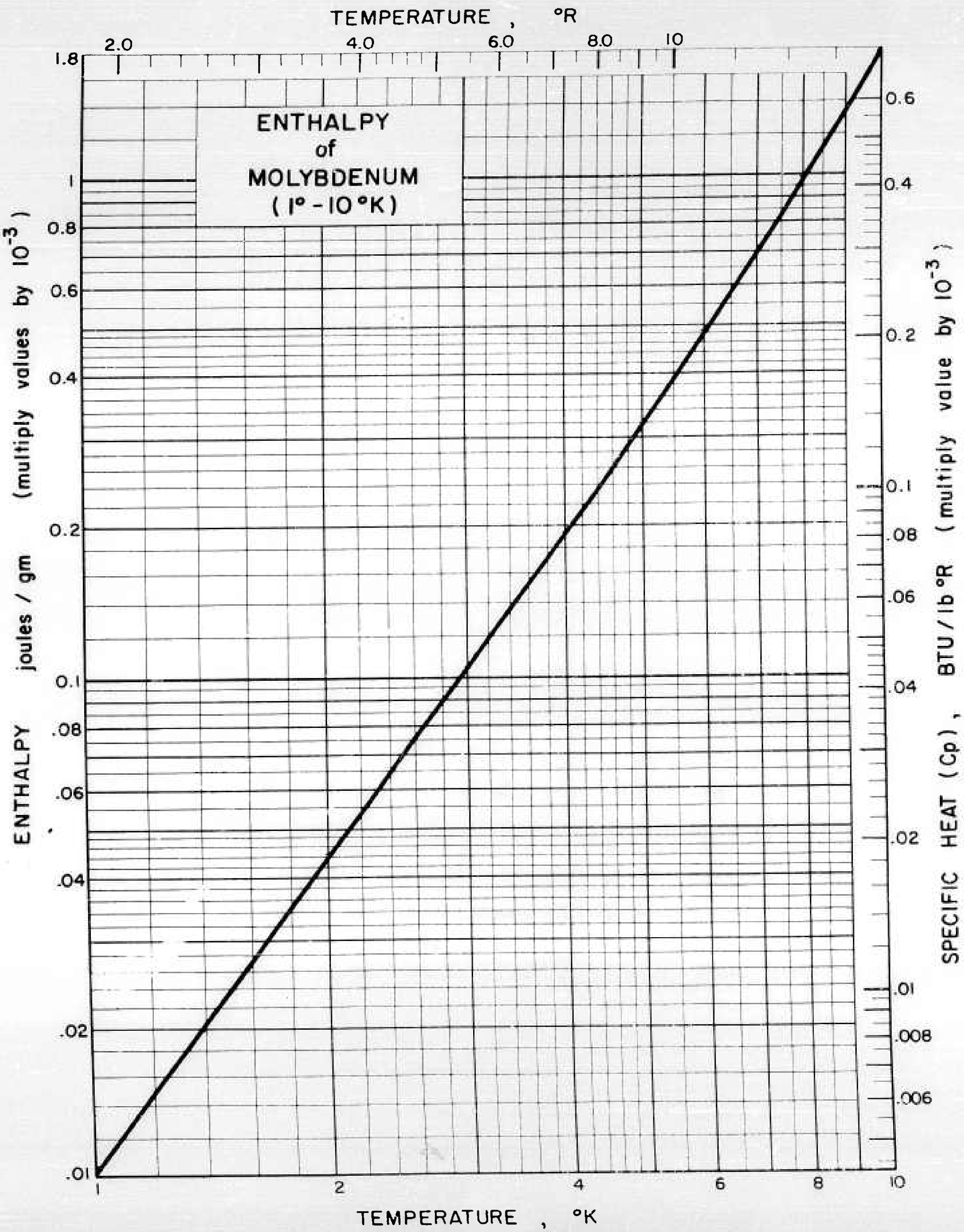
Table of Selected Values

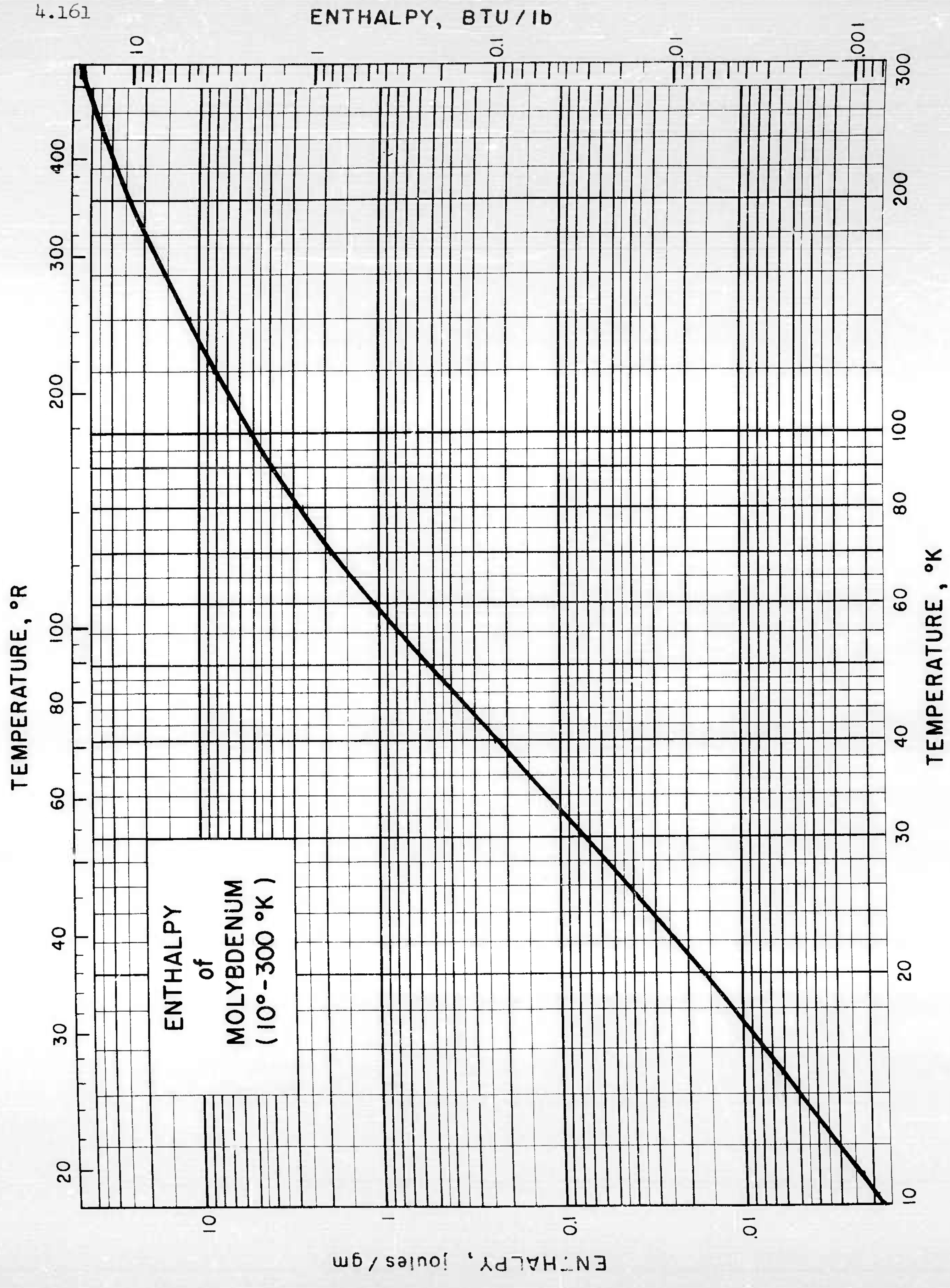
Temp. °K	C_p j/gm-°K	H j/gm	Temp. °K	C_p j/gm-°K	H j/gm
1	0.000 0229	0.000 0105	70	0.0838	1.80
2	.000 0472	.000 0445	80	.104	2.74
3	.000 0745	.000 105	90	.123	3.88
4	.000 106	.000 194	100	.139	5.20
6	.000 191	.000 484	120	.168	8.27
8	.000 317	.000 981	140	.187	11.8
10	.000 498	.001 78	160	.202	15.7
15	.001 31	.006 10	180	.213	19.9
20	.002 87	.016 1	200	.222	24.2
25	.005 77	.037 4	220	.229	28.7
30	.009 60	.072 9	240	.236	33.4
40	.023 6	.232	260	.240	38.1
50	.041 0	.554	280	.243	43.0
60	.061 9	1.07	300	.246	47.9

RJC/JJG/VDA Issued: 12-18-59
Revised: 5-20-60


TEMPERATURE , °R
2.0
4.0
6.0
8.0
10
SPECIFIC HEAT
of
MOLYBDENUM
(1° - 10 °K)
SPECIFIC HEAT (Cp) , joules / gm °K (multiply value by 10^-3)
0.4
0.2
0.1
.08
.06
.04
.02
SPECIFIC HEAT (Cp) , BTU / lb °R (multiply value by 10^-3)
.1
.08
.06
.04
.02
.01
.008
.006
1
2
4
6
8
10
TEMPERATURE , °K


TEMPERATURE, °R
20
30
40
60
80
100
200
300
400
SPECIFIC HEAT (C_p), joules/gm °K
0.1
.01
.001
SPECIFIC HEAT (C_p), BTU/lb-°R
.01
.001
.0001
SPECIFIC HEAT of
MOLYBDENUM
(10° - 300° K)
10
20
30
40
60
80
100
200
300
TEMPERATURE, °K


TEMPERATURE , °R
2.0
4.0
6.0
8.0
10
ENTHALPY
of
MOLYBDENUM
(1° - 10 °K)
ENTHALPY joules / gm (multiply values by 10^{-3})
1.8
1
0.8
0.6
0.4
0.2
0.1
.08
.06
.04
.02
.01
SPECIFIC HEAT (Cp), BTU / lb °R (multiply value by 10^{-3})
0.6
0.4
0.2
0.1
.08
.06
.04
.02
.01
.008
.006
1
2
4
6
8
10
TEMPERATURE , °K


ENTHALPY, BTU/lb
10
1
0.1
.01
.001
TEMPERATURE, °R
400
300
200
100
80
60
40
30
20
TEMPERATURE, °K
300
200
100
80
60
40
30
20
10
ENTHALPY
of
MOLYBDENUM
(10°-300°K)
10
1
0.1
.01
ENTHALPY, joules/gm

SPECIFIC HEAT, ENTHALPY of TUNGSTEN

Sources of Data:

Horowitz, M. and Daunt, J. G., Phys. Rev. 91, 1099-1106 (1953)

Lange, F., Z. physik. Chem. 110, 343 (1924)

Rayne, J. A., Phys. Rev. 95, 1428 (1954)

Wolcott, N. M., Conf. Physique Basses Temp. Paris (1955)

Other References:

Bronson, H. L., Chisholm, H. M. and Dockerty, S. M., Can. J. Research 8, 282 (1933)

Silvidi, A. A. and Daunt, J. G., Phys. Rev. (2) 77, 125-9 (1950)

Zwikker, C. and Schmidt, G., Physik. Z. 52, 668-77 (1928)

Comments:

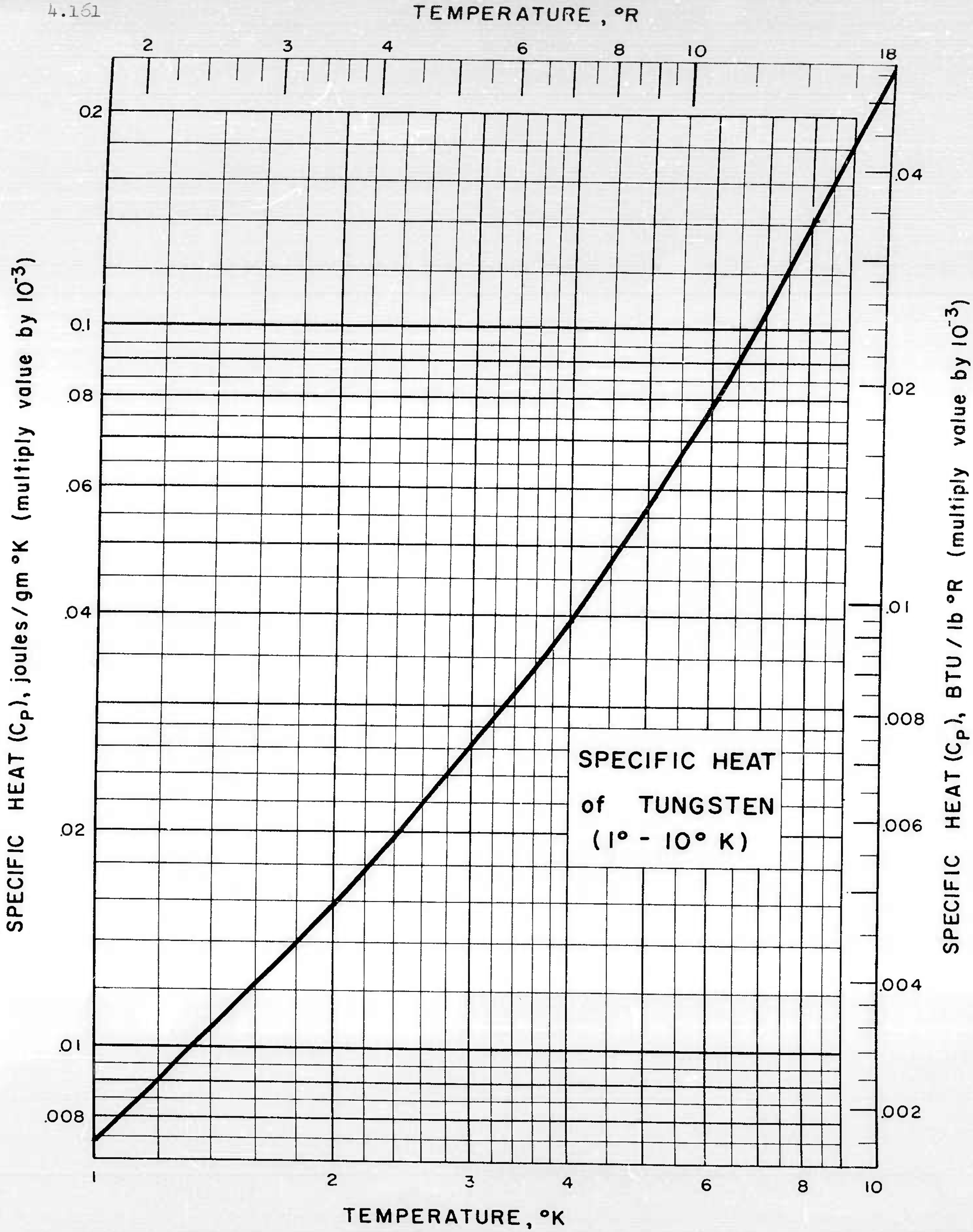
For the temperature range from 0° to 4°K the specific heat C_p follows the equation:

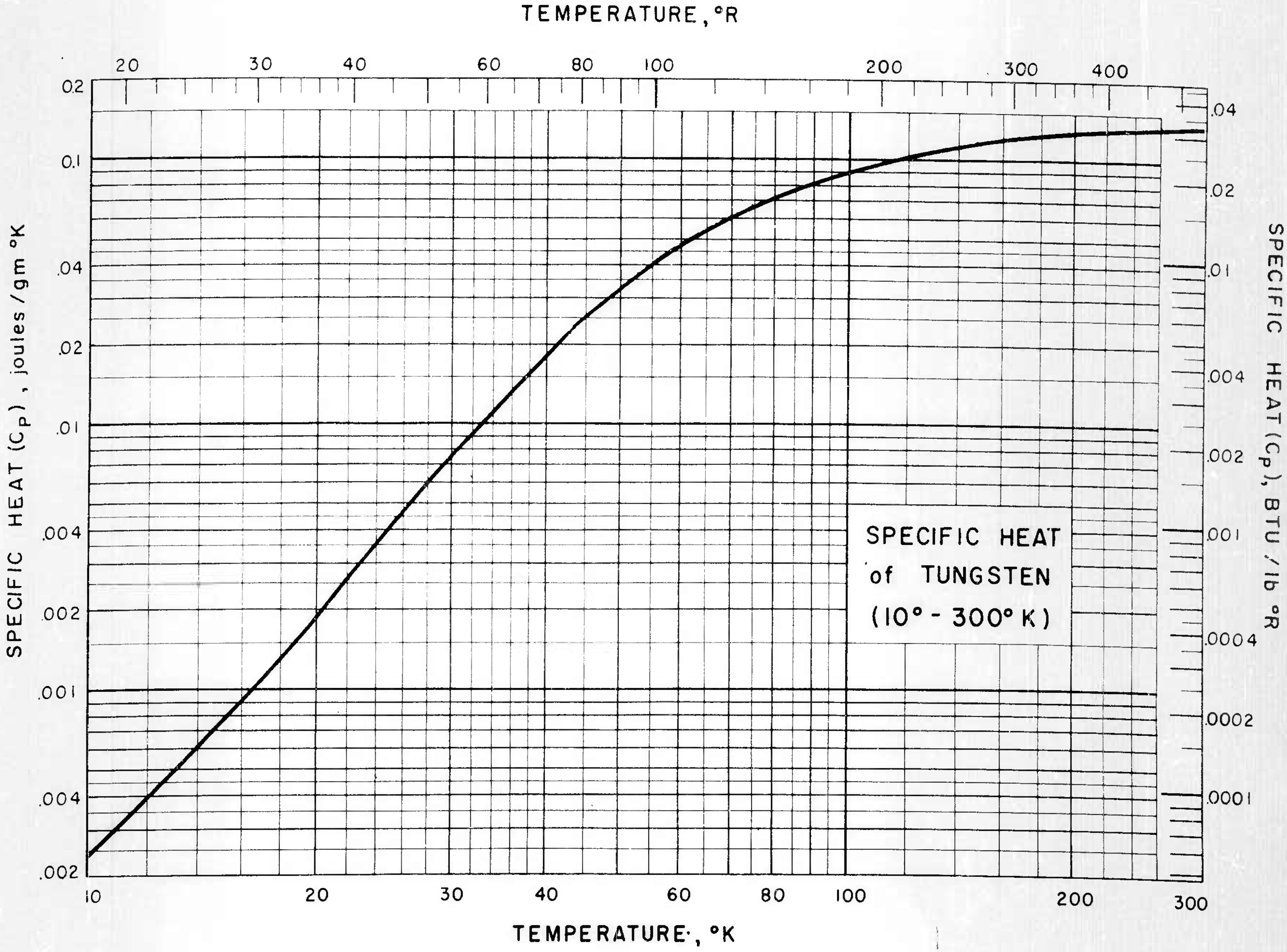
$$C_p = (7.3\pm1) \times 10^{-6} T + 10.6 \left(\frac{T}{405\pm20}\right)^3 \text{ j/gm-°K}$$

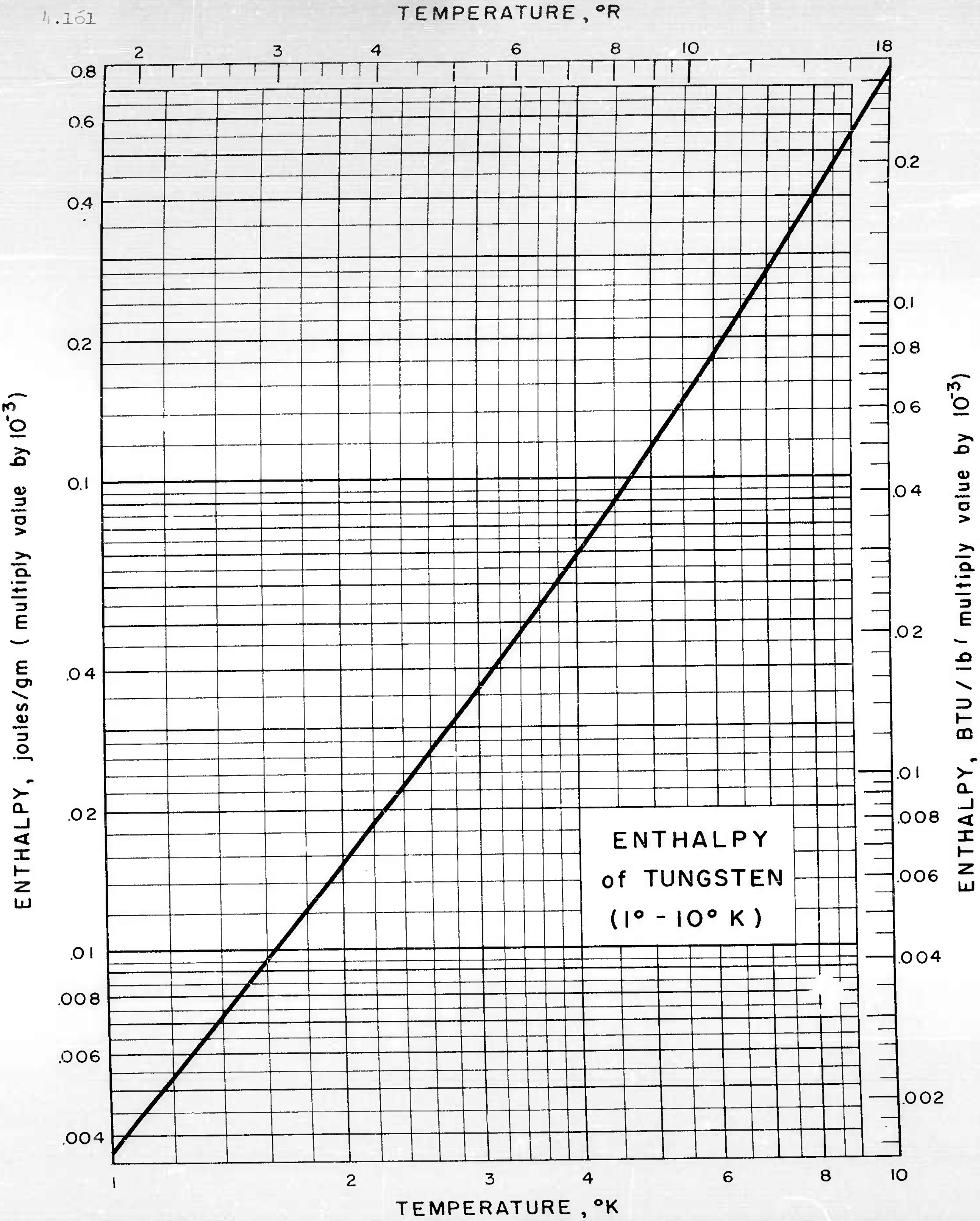
Table of Selected Values

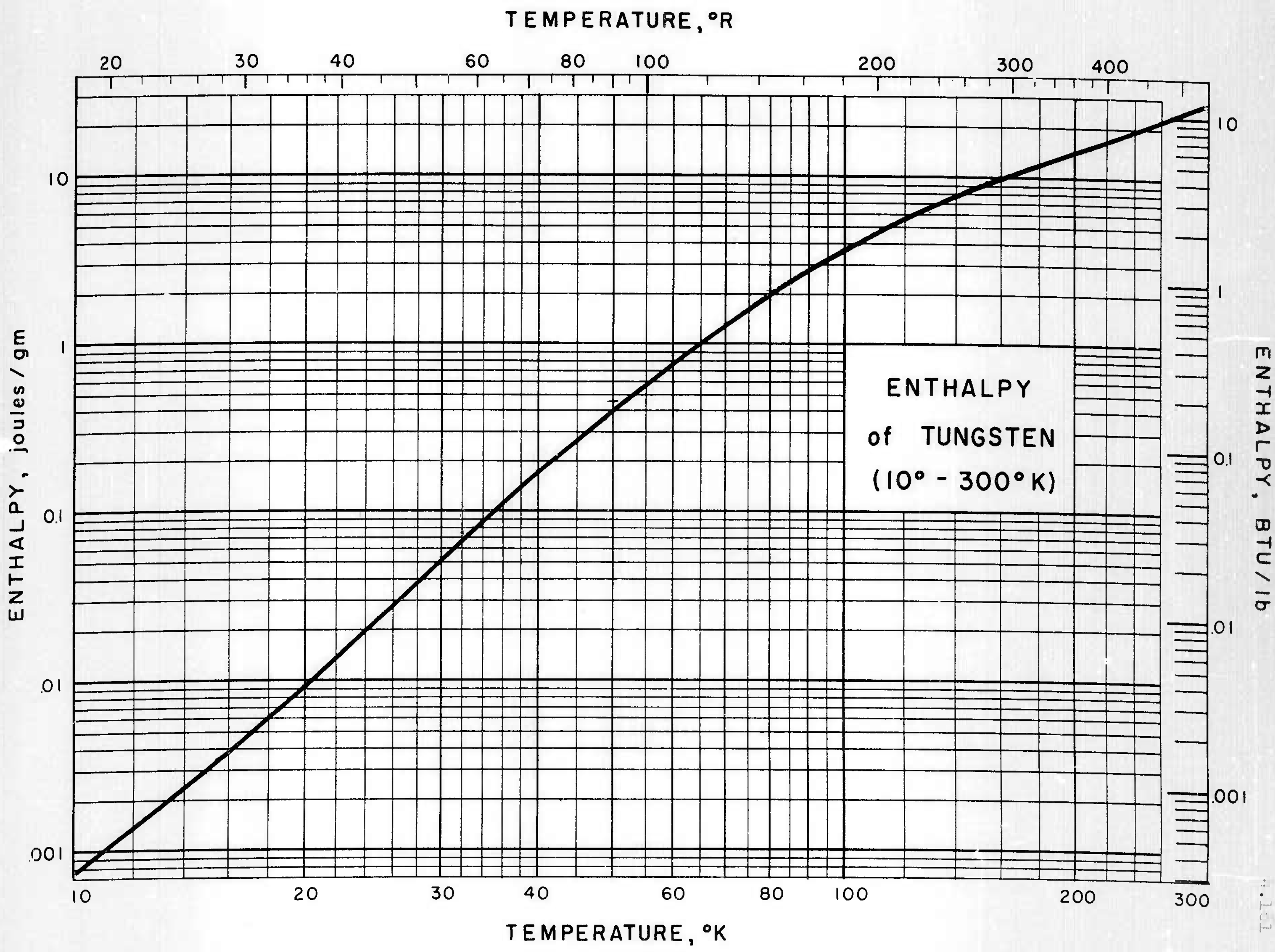
Temp. °K	C_p j/gm-°K	H j/gm	Temp. °K	C_p j/gm-°K	H j/gm
1	0.000 0074	0.000 0037	70	0.0605	1.39
2	.000 0158	.000 0152	80	.0715	2.05
3	.000 0262	.000 0360	90	.0810	2.81
4	.000 0393	.000 0685	100	.0888	3.66
6	.000 0783	.000 182	120	.101	5.57
8	.000 141	.000 396	140	.110	7.68
10	.000 234	.000 765	160	.117	9.95
15	.000 725	.002 97	180	.122	12.3
20	.001 89	.009 27	200	.125	14.8
25	.004 21	.023 7	220	.128	17.4
30	.007 83	.053 4	240	.130	20.0
40	.018 4	.181	260	.132	22.6
50	.033 2	.436	280	.134	25.3
60	.048 3	.843	300	.136	28.0

RJC/JJG Issued: 12-18-59
Revised: 5-20-60


TEMPERATURE, °R
2
3
4
6
8
10
18
SPECIFIC HEAT (C_p), joules / gm °K (multiply value by 10^{-3})
.02
0.1
.08
.06
.04
.02
.01
.008
SPECIFIC HEAT (C_p), BTU / lb °R (multiply value by 10^{-3})
.04
.02
.01
.008
.006
.004
.002
SPECIFIC HEAT
of TUNGSTEN
(1° - 10° K)
1
2
3
4
6
8
10
TEMPERATURE, °K


SPECIFIC HEAT
of TUNGSTEN
(10° - 300° K)
TEMPERATURE, °R
TEMPERATURE, °K
SPECIFIC HEAT (Cp), joules/gm °K
SPECIFIC HEAT (Cp), BTU/lb °R


TEMPERATURE, °R
2
3
4
6
8
10
18
0.8
0.6
0.4
0.2
0.1
.04
.02
.01
.008
.006
.004
ENTHALPY, joules/gm (multiply value by 10^{-3})
0.2
0.1
.08
.06
.04
.02
.01
.008
.006
.004
.002
ENTHALPY, BTU / lb (multiply value by 10^{-3})
ENTHALPY
of TUNGSTEN
(1° - 10° K)
1
2
3
4
6
8
10
TEMPERATURE, °K


TEMPERATURE, °R
20
30
40
60
80
100
200
300
400
ENTHALPY
of TUNGSTEN
(10° - 300°K)
ENTHALPY, joules/gm
10
1
0.1
.01
.001
ENTHALPY, BTU/lb
10
1
0.1
.01
.001
10
20
30
40
60
80
100
200
300
TEMPERATURE, °K

SPECIFIC HEAT, ENTHALPY OF MANGANESE: α FORM

Sources of Data:

Booth, G. L., Hoare, F. E., and Murphy, B. T., Proc. Phys. Soc. (London) 68B, 830 (1955)

Guthrie, G., Friedberg, S. A., and Goldman, J. E., Phys. Rev. 98, 1181 (1955)

Shomate, E. H., J. Chem. Phys. 13, 326 (1945)

Other References:

Armstrong, L. D., and Grayson-Smith, H., Can. J. Research A27, 9 (1949)

Elson, R. G., Grayson-Smith, H., and Wilhelm, J. O., Can. J. Research A18, 83 (1940)

Kelley, K. K., J. Am. Chem. Soc. 61, 203 (1939)

Richards, T. W., and Jackson, F. G., Z. physik. Chem. 70, 414 (1910)

Wolcott, N. M., Conf. Phys. basses temp. (1955)

Comments:

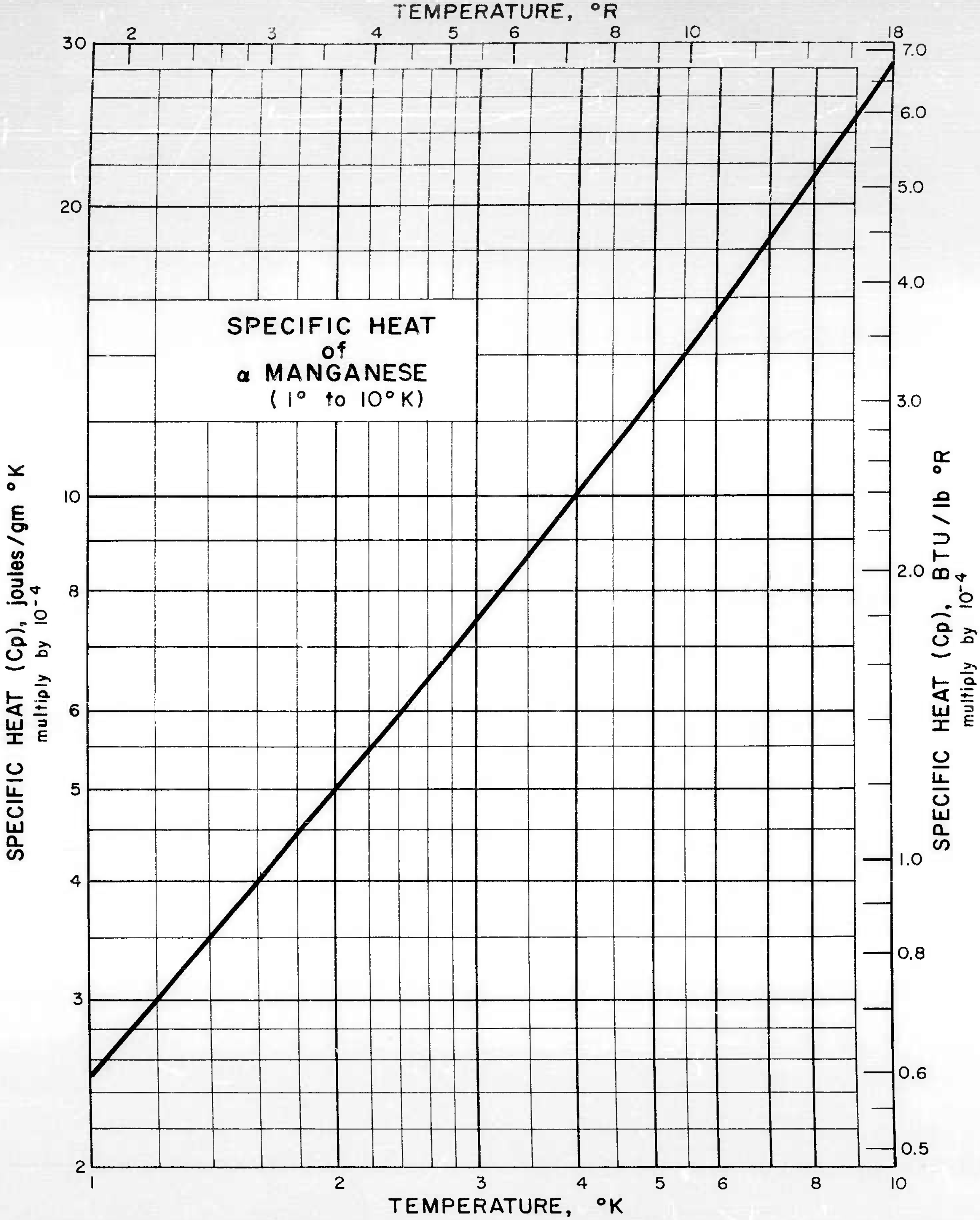
α Mn is stable at all temperatures up to about 730°C. A small peak in C_p is found centering at 95°K which is due to an antiferromagnetic transition (Neel point). The data of Armstrong and Grayson-Smith, Elson, Grayson-Smith and Wilhelm, and Wolcott in the region up to 20°K form a self-consistent set that is 20 to 30% higher than the data of Booth, Hoare and Murphy, and Guthrie, Friedberg and Goldman. The latter have been adopted because these authors present more conclusive evidence of the chemical and phase purity of their samples.

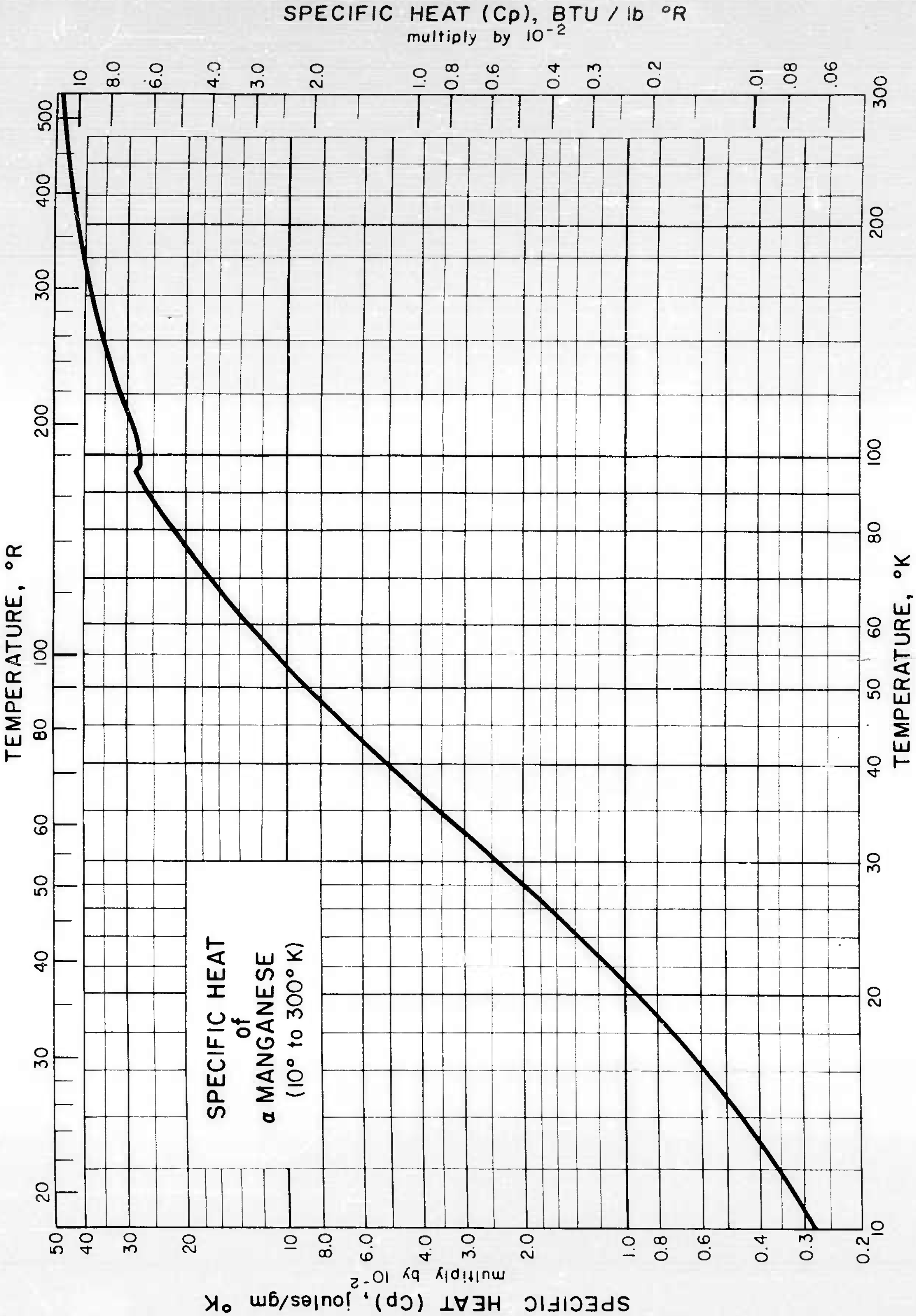
Table of Selected Values

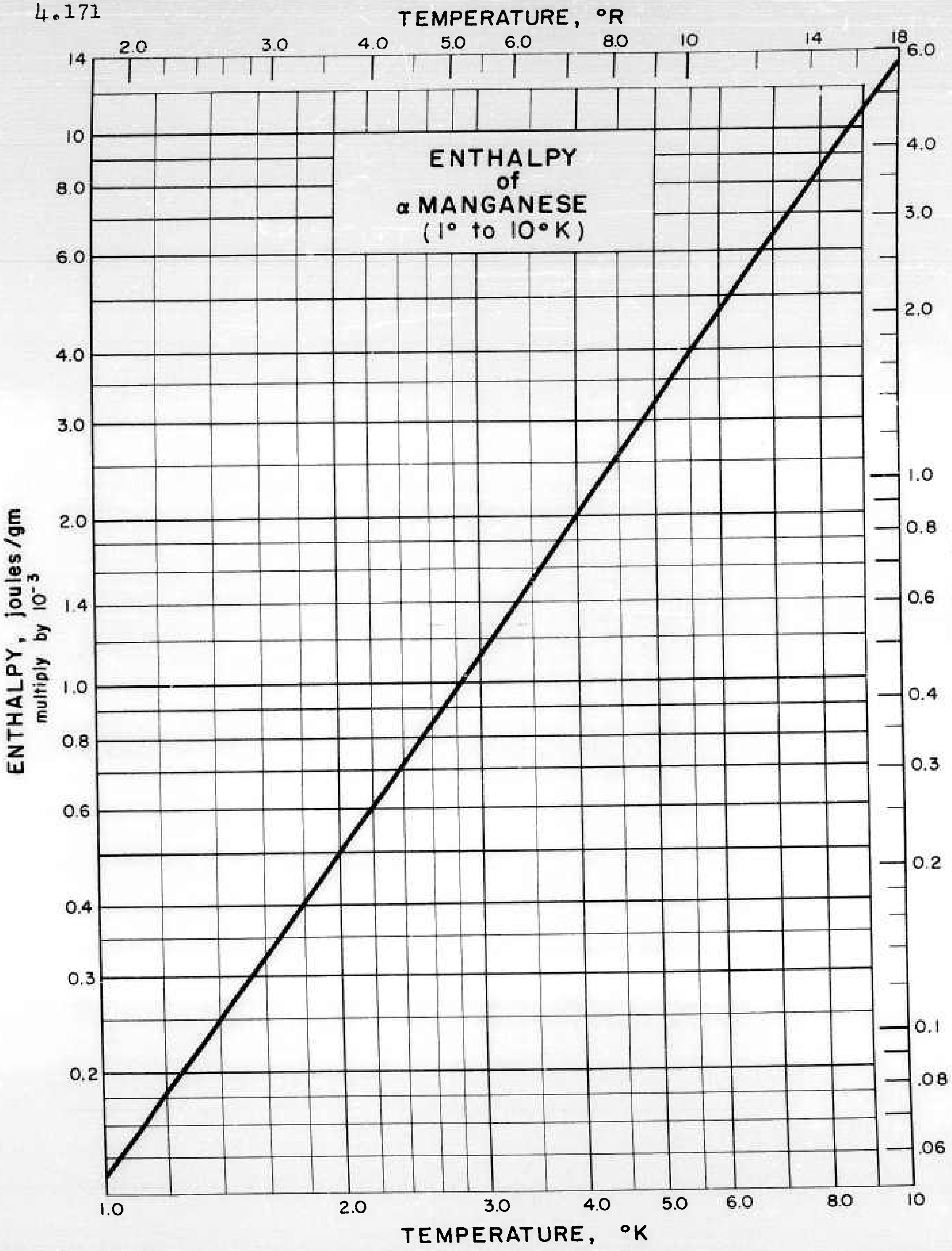
T °K	Cp j/g-deg K	H j/g	T °K	Cp j/g-deg K	H j/g
1	0.000 25	0.000 13	70	0.171	3.82
2	.000 50	.000 50	80	.214	5.75
3	.000 75	.001 12	90	.257	8.11
4	.001 01	.002 01	95	.273*	9.44
6	.001 56	.004 6	100	.267	10.79
8	.002 16	.008 3	120	.312	16.6
10	.002 82	.013 3	140	.349	23.2
15	.005 2	.032 7	160	.379	30.5
20	.009 0	.067	180	.402	38.3
25	.014 7	.126	200	.420	46.5
30	.023	.219	220	.435	55.1
40	.050	.57	240	.448	63.9
50	.087	1.25	260	.460	73.0
60	.129	2.32	280	.470	82.3
			300	.480	91.8

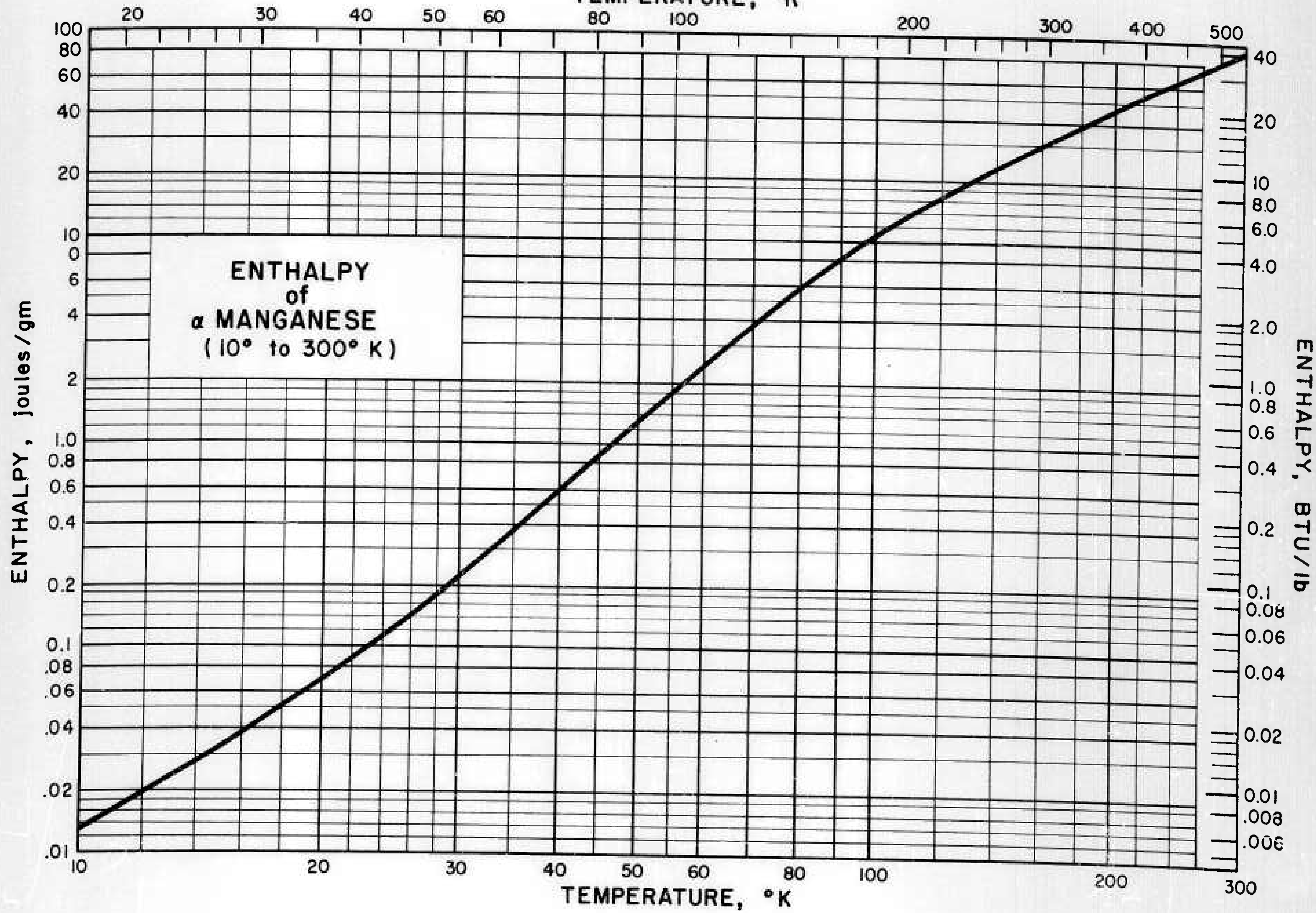
*Peak due to antiferromagnetic transition.

RJC Issued: 6-5-59
Revised: 5-20-60


TEMPERATURE, °R
2
3
4
5
6
8
10
18
SPECIFIC HEAT
of
α MANGANESE
(1° to 10° K)
SPECIFIC HEAT (Cp), joules/gm °K
multiply by 10^{-4}
SPECIFIC HEAT (Cp), BTU/lb °R
multiply by 10^{-4}
30
20
10
8
6
5
4
3
2
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.8
0.6
0.5
1
2
3
4
5
6
8
10
TEMPERATURE, °K


SPECIFIC HEAT (Cp), BTU / lb °R
multiply by 10^-2
TEMPERATURE, °R
TEMPERATURE, °K
SPECIFIC HEAT
of
α MANGANESE
(10° to 300° K)
SPECIFIC HEAT (Cp), joules/gm °K
multiply by 10^-2


TEMPERATURE, °R
2.0
3.0
4.0
5.0
6.0
8.0
10
14
18
ENTHALPY
of
α MANGANESE
(1° to 10° K)
14
10
8.0
6.0
4.0
3.0
2.0
1.4
1.0
0.8
0.6
0.4
0.3
0.2
ENTHALPY, joules/gm
multiply by 10^{-3}
6.0
4.0
3.0
2.0
1.0
0.8
0.6
0.4
0.3
0.2
0.1
.08
.06
ENTHALPY, BTU/lb
multiply by 10^{-3}
1.0
2.0
3.0
4.0
5.0
6.0
8.0
10
TEMPERATURE, °K


TEMPERATURE, °R
TEMPERATURE, °K
ENTHALPY, joules/gm
ENTHALPY, BTU/lb
ENTHALPY
of
α MANGANESE
(10° to 300° K)

SPECIFIC HEAT of MANGANESE, β FORM

Source of Data:

Booth, G. L., Hoare, F. E., and Murphy, B. T., Proc. Phys. Soc. (London) 68B, 830 (1955)

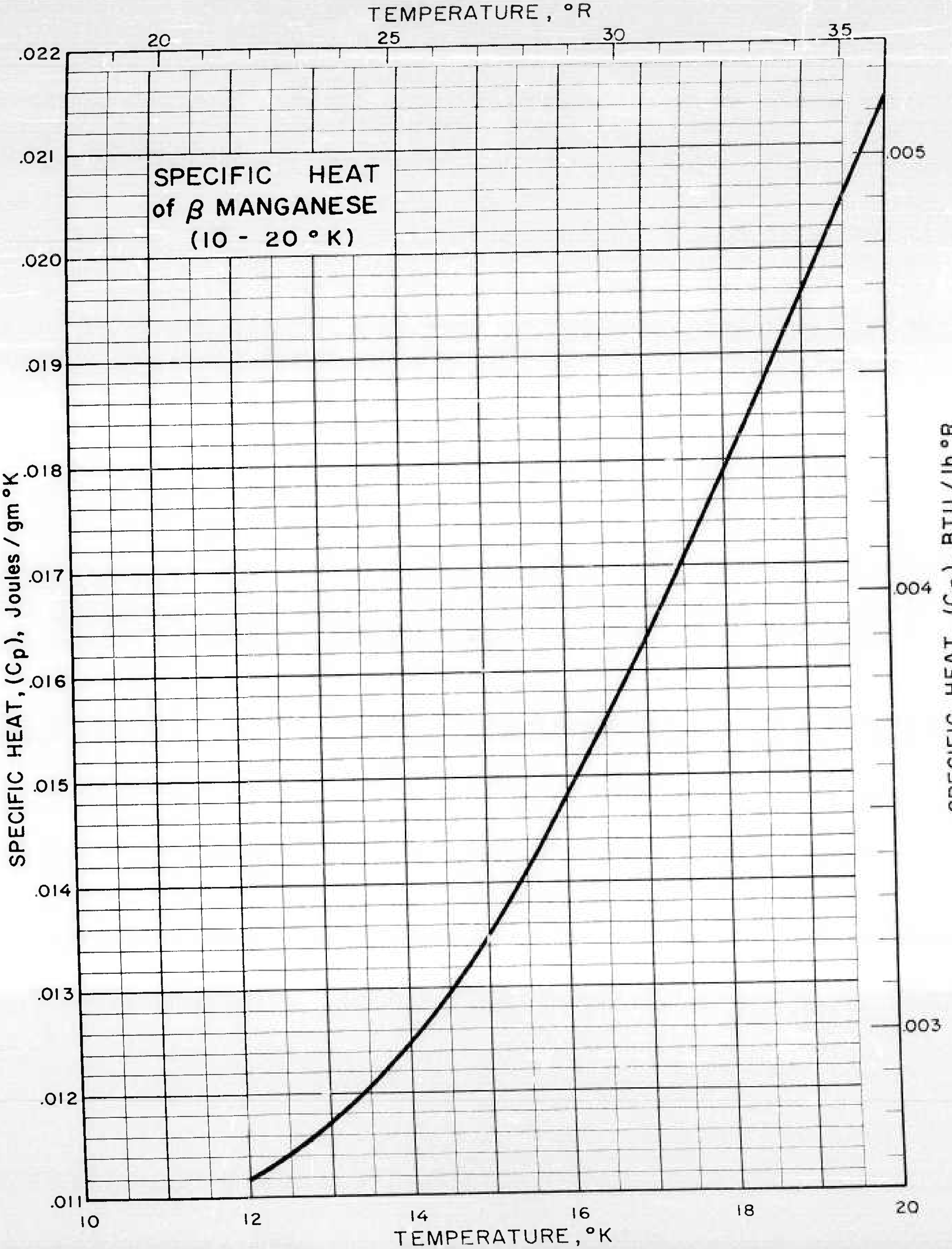
Comments:

β Mn is stable between about 730°C and 1100°C. The sample of Booth, Hoare and Murphy was produced by heating ordinary (α) manganese to 1120°C in argon, then quenching in water.

Table of Selected Values

T °K	Cp j/gm-°K
12	0.0112
13	.0117
14	.0125
15	.0135
16	.0148
17	.0163
18	.0179
19	.0196
20	.0214

RJC Issued: 6-15-59


TEMPERATURE, °R
20
25
30
35
.022
.021
.020
.019
.018
.017
.016
.015
.014
.013
.012
.011
SPECIFIC HEAT of β MANGANESE (10 - 20 °K)
SPECIFIC HEAT, (Cp), Joules / gm °K
.005
.004
.003
SPECIFIC HEAT, (Cp), BTU / lb °R
10
12
14
16
18
20
TEMPERATURE, °K

SPECIFIC HEAT, ENTHALPY of MANGANESE: γ FORM

Source of Data:

Shomate, C. H., J. Chem. Phys. 13, 326 (1945)

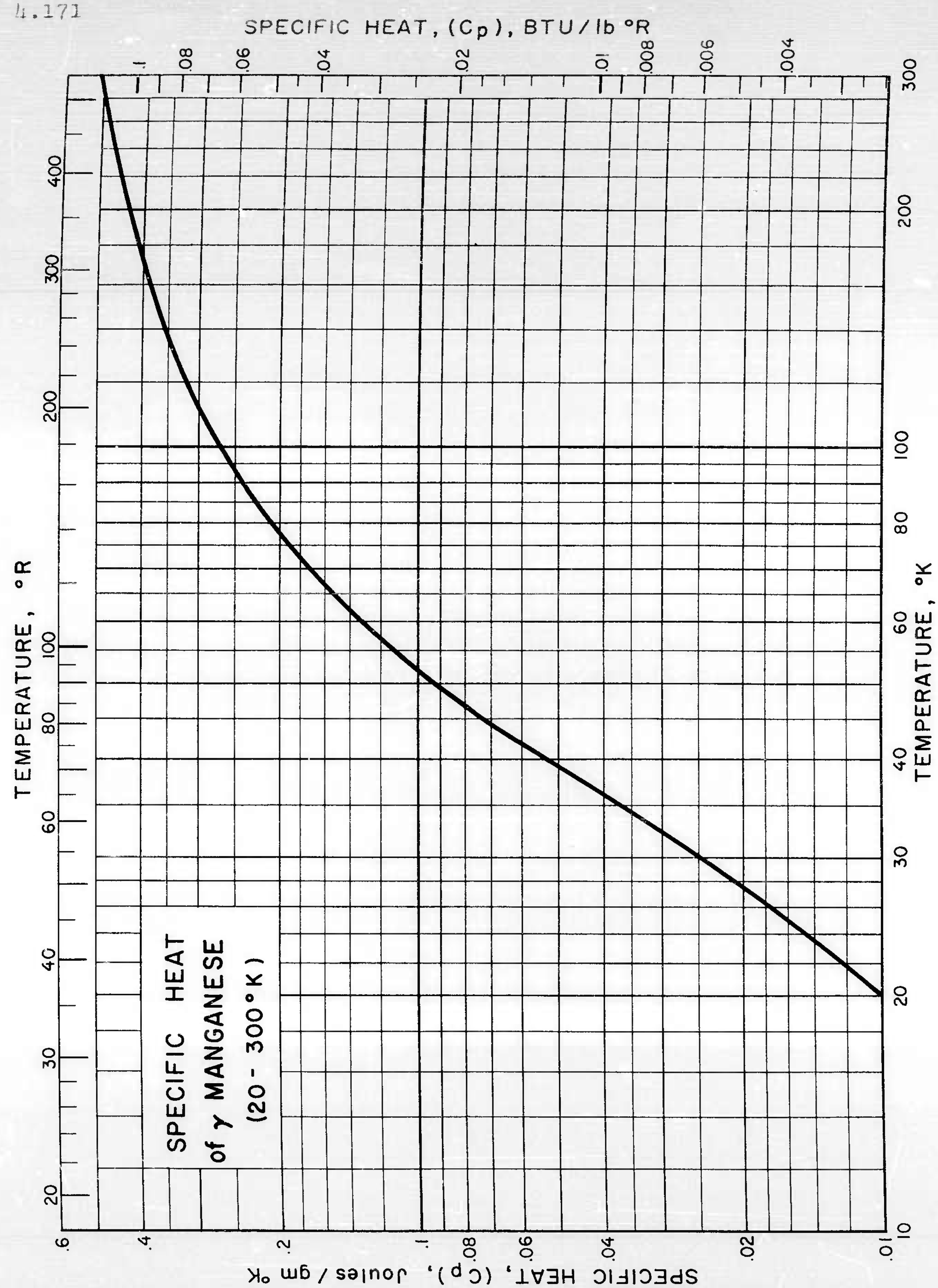
Comments:

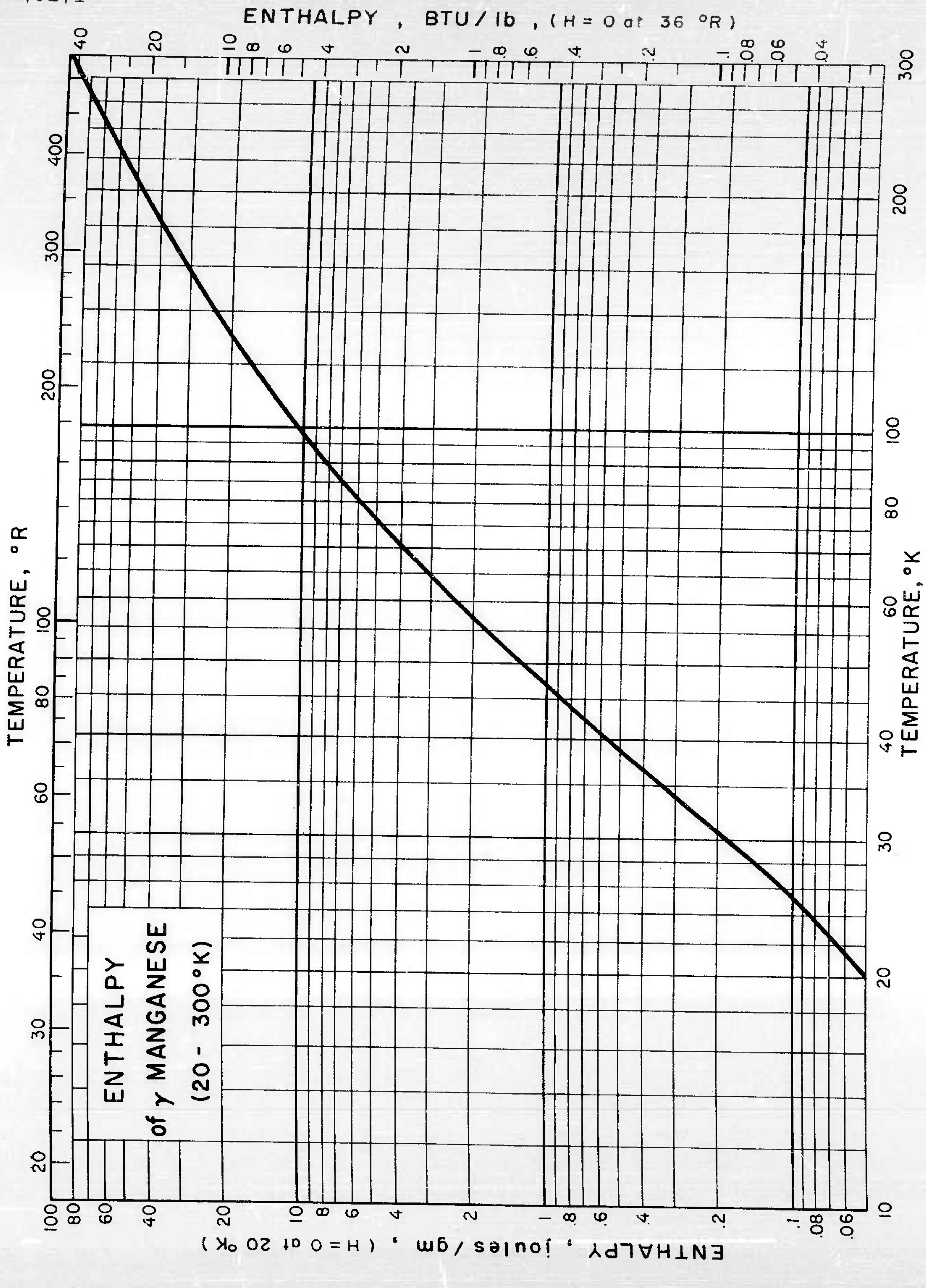
γ Mn is a ductile form that is stable between about 1100° and 1135°C when pure. It is often found as a separate phase in manganese alloys. The sample measured by Shomate was produced by electrolytic deposition.

Table of Selected Values

T °K	Cp j/gm-°K	H j/gm	T °K	Cp j/gm-°K	H j/gm
20	0.01	0.05	120	0.318	16.5
30	.025	0.19	140	.356	23.3
40	.053	0.55	160	.386	30.7
50	.092	1.27	180	.410	38.6
60	.133	2.39	200	.430	47.0
70	.172	3.92	220	.447	55.8
80	.208	5.82	240	.463	64.9
90	.240	8.06	260	.477	74.3
100	.270	10.61	280	.490	84.0
			300	.503	93.9

RJC Issued: 6-15-59


SPECIFIC HEAT, (Cp), BTU/lb °R
.1
.08
.06
.04
.02
.01
.008
.006
.004
TEMPERATURE, °R
20
30
40
60
80
100
200
300
400
TEMPERATURE, °K
10
20
30
40
60
80
100
200
300
SPECIFIC HEAT
of γ MANGANESE
(20 - 300°K)
SPECIFIC HEAT, (Cp), Joules / gm °K
.6
.4
.2
.1
.08
.06
.04
.02
.01


ENTHALPY of γ MANGANESE (20 - 300°K)
ENTHALPY , BTU/lb , (H = 0 at 36 °R)
ENTHALPY , joules/gm , (H = 0 at 20 °K)
TEMPERATURE, °R
TEMPERATURE, °K

SPECIFIC HEAT and ENTHALPY of α-IRON

Sources of Data:

Duyckaerts, G., Physica 6, 401-8 (1939)

Keesom, W. H. and Kurrelmayer, B., Physica 6, 633 (1939)

Kelley, K. K., J. Chem. Phys. 11, 16-8 (1943)

Other References:

Austin, J. B., Ind. Eng. Chem. 24, 1225 (1932)

Behn, U., Ann. Physik (3) 66, 237 (1898)

Duyckaerts, G., Mem. soc. roy. sci. Liege 6, 193 (1945)

Eucken, A. and Werth, H., Z. anorg. u. allgem. Chem. 188, 152 (1930)

Griffiths, E. G. and Griffiths, E., Phil. Trans. Roy. Soc. London A214, 319 (1914) and Proc. Roy. Soc. (London) A90, 557 (1914)

Gunther. P., Ann. Physik (4) 51, 828 (1916)

Richards, T. W. and Jackson, F. G., Z. physik. Chem. 70, 414 (1910)

Rodebush, W. H. and Michalek, J. C., J. Am. Chem. Soc. 47, 2117 (1925)

Schmitz. H. E., Proc. Roy. Soc. (London) 72, 177 (1903)

Simon, F., Z. angew. Chem. 41, 1113 (1928)

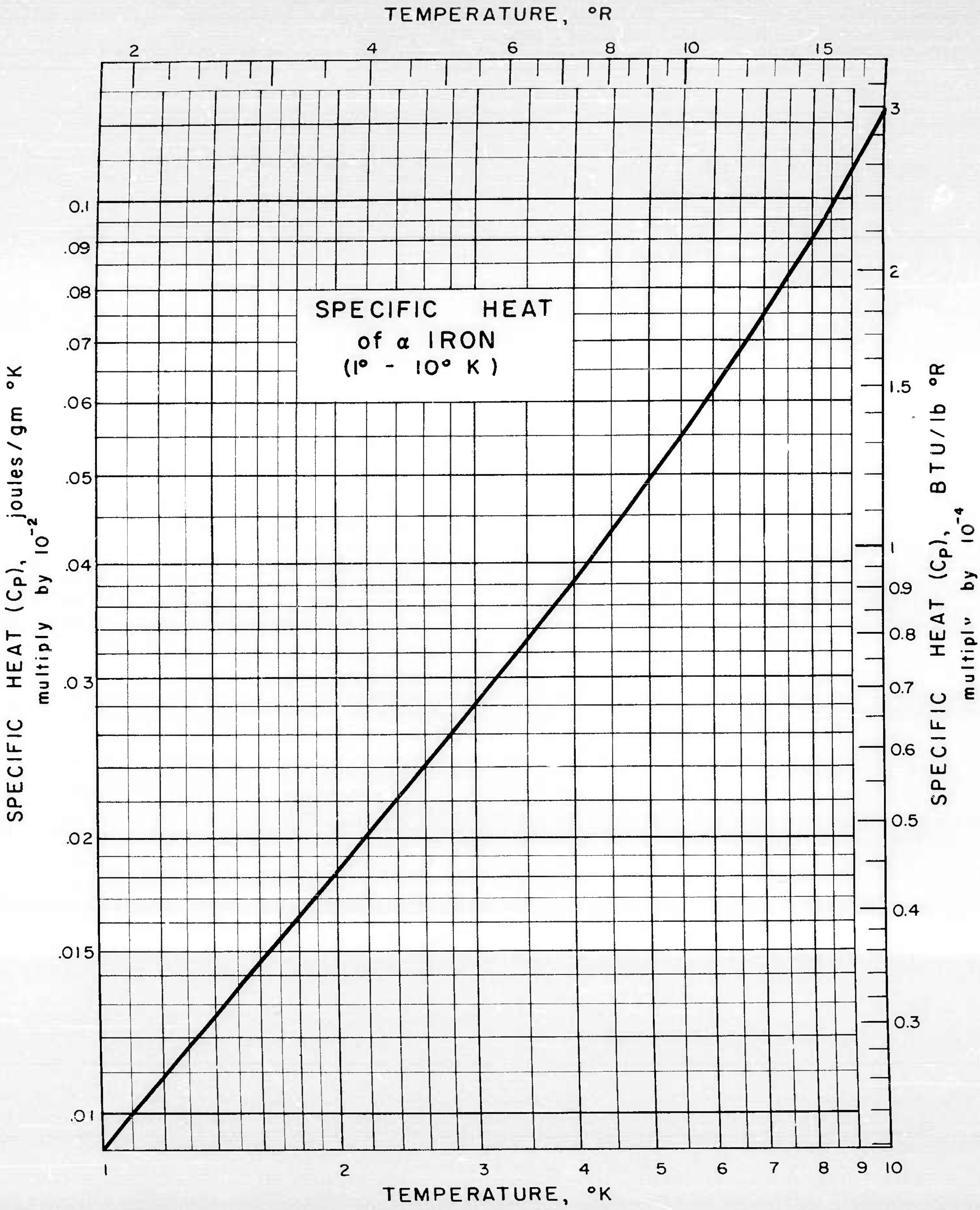
Simon, F. and Swain, R. C., Z. physik. Chem. B28, 189 (1935)

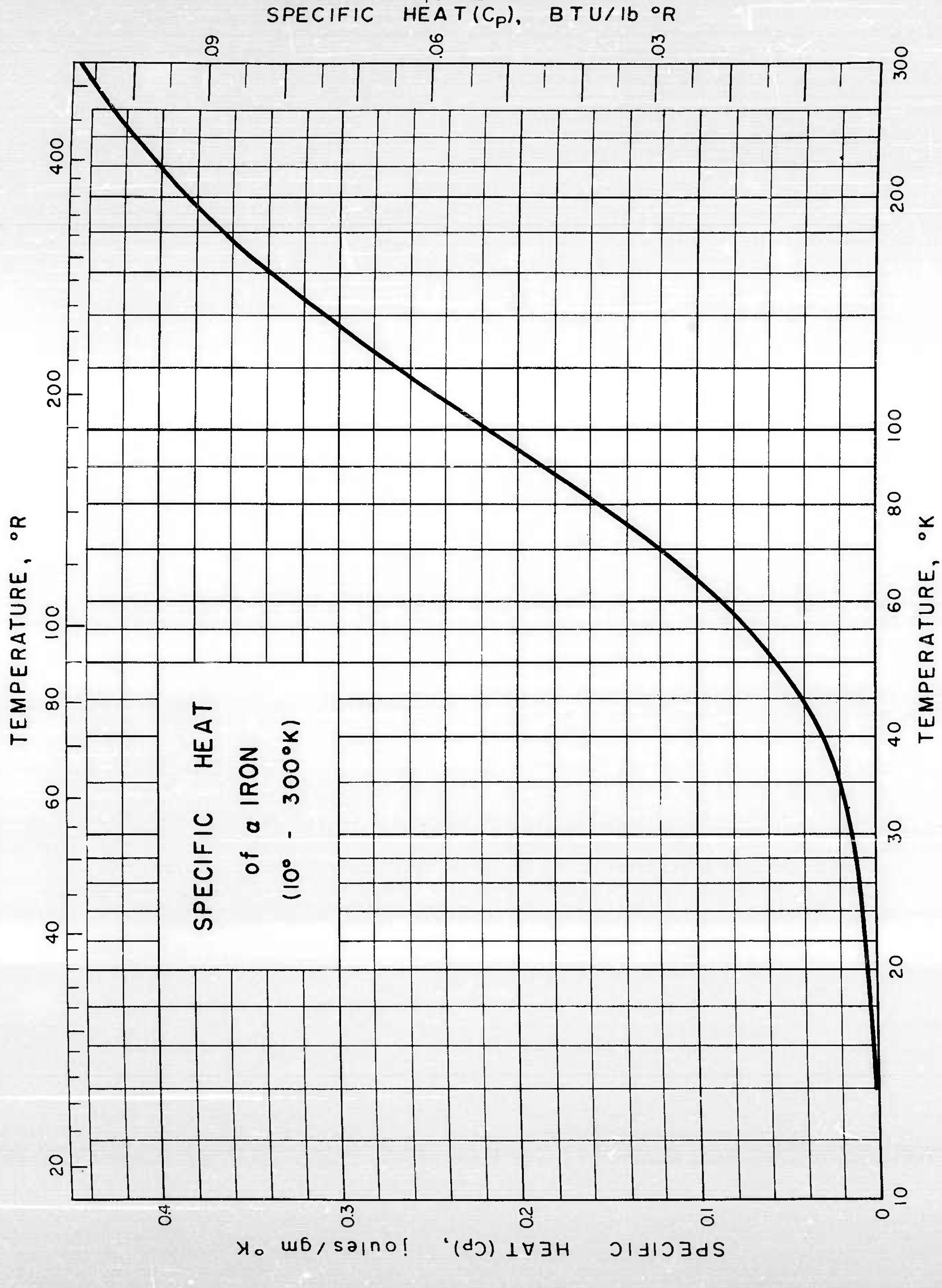
Comments:

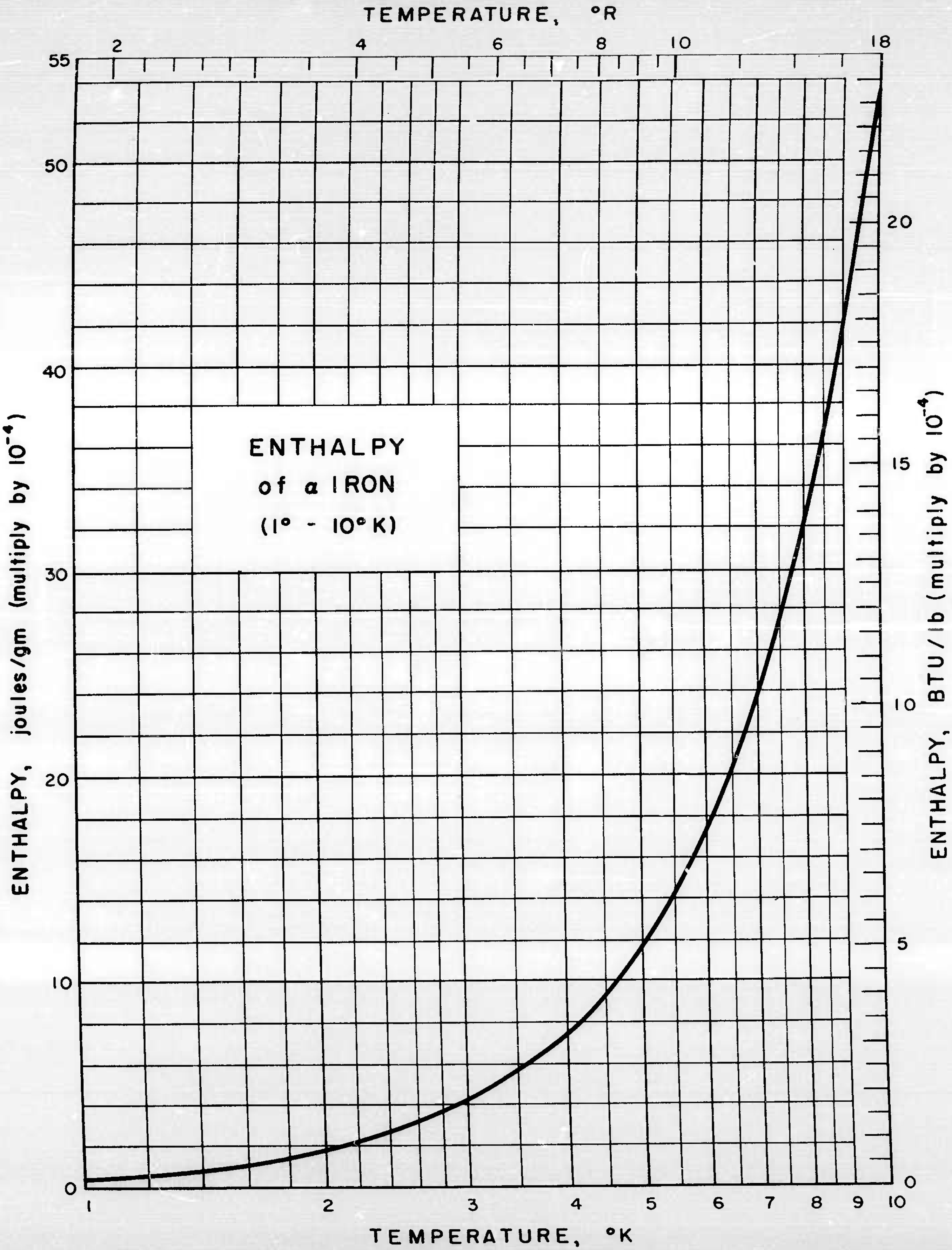
α -Iron is the form that is stable up to the Curie point at 760°C. It has a body-centered cubic lattice.

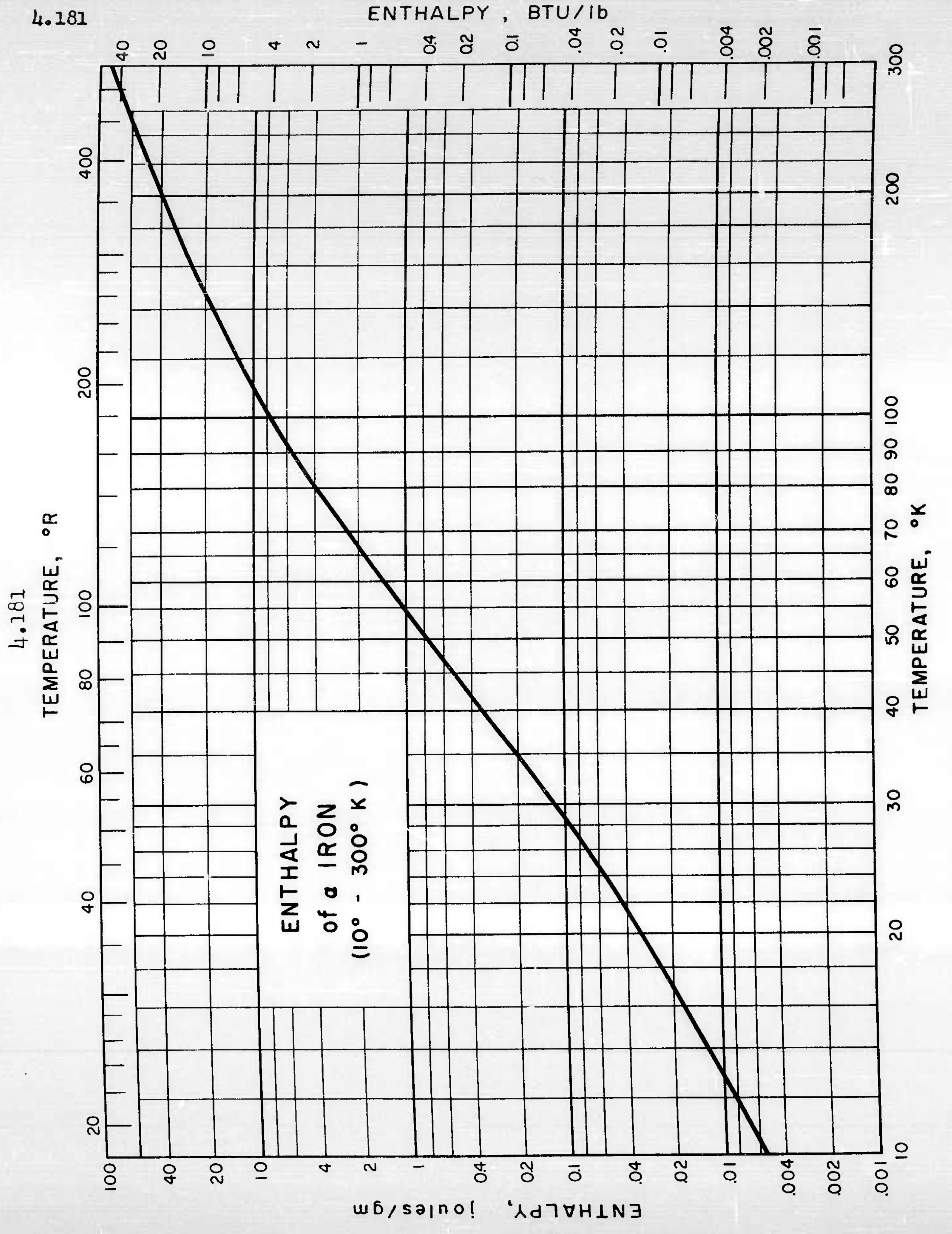
T °K	C_p j/gm-°K	H j/gm	T °K	C_p j/gm-°K	H j/gm
1	0.000 090	0.000 045	70	0.121	2.46
2	.000 183	.000 181	80	.154	3.84
3	.000 279	.000 412	90	.186	5.55
4	.000 382	.000 742	100	.216	7.56
6	.000 615	.001 73	120	.267	12.40
8	.000 90	.003 23	140	.307	18.16
10	.001 24	.005 37	160	.339	24.63
15	.002 49	.014 5	180	.364	31.67
20	.004 5	.031 6	200	.384	39.2
25	.007 5	.061	220	.401	47.0
30	.012 4	.110	240	.415	55.2
40	.029	.31	260	.428	63.6
50	.055	.73	280	.439	72.3
60	.087	1.43	300	.447	81.1

RJC Issued: 12-15-59


TEMPERATURE, °R
2
4
6
8
10
15
SPECIFIC HEAT
of α IRON
(1° - 10° K)
SPECIFIC HEAT (CP), joules/gm °K
multiply by 10^-2
0.1
.09
.08
.07
.06
.05
.04
.03
.02
.015
.01
SPECIFIC HEAT (CP), BTU/lb °R
multiply by 10^-4
3
2
1.5
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
1
2
3
4
5
6
7
8
9
10
TEMPERATURE, °K


SPECIFIC HEAT(Cp), BTU/lb °R
.09
.06
.03
TEMPERATURE, °R
400
200
100
80
60
40
20
TEMPERATURE, °K
300
200
100
80
60
40
30
20
10
SPECIFIC HEAT of a IRON (10° - 300°K)
SPECIFIC HEAT (Cp), joules/gm °K
0.4
0.3
0.2
0.1
0


TEMPERATURE, °R
2
4
6
8
10
18
55
50
40
30
20
10
0
ENTHALPY of α IRON (1° - 10° K)
ENTHALPY, joules/gm (multiply by 10^{-4})
20
15
10
5
0
ENTHALPY, BTU/lb (multiply by 10^{-4})
1
2
3
4
5
6
7
8
9
10
TEMPERATURE, °K


ENTHALPY , BTU/lb
40 20 10 4 2 1 0.4 0.2 0.1 .04 .02 .01 .004 .002 .001
ENTHALPY, joules/gm
100 40 20 10 4 2 1 0.4 0.2 0.1 .04 .02 .01 .004 .002 .001
TEMPERATURE, °R
20 40 60 80 100 200 400
TEMPERATURE, °K
10 20 30 40 50 60 70 80 90 100 200 300
4.181
ENTHALPY
of α IRON
(10° - 300° K)

SPECIFIC HEAT, ENTHALPY of γ - IRON

Sources of Data:

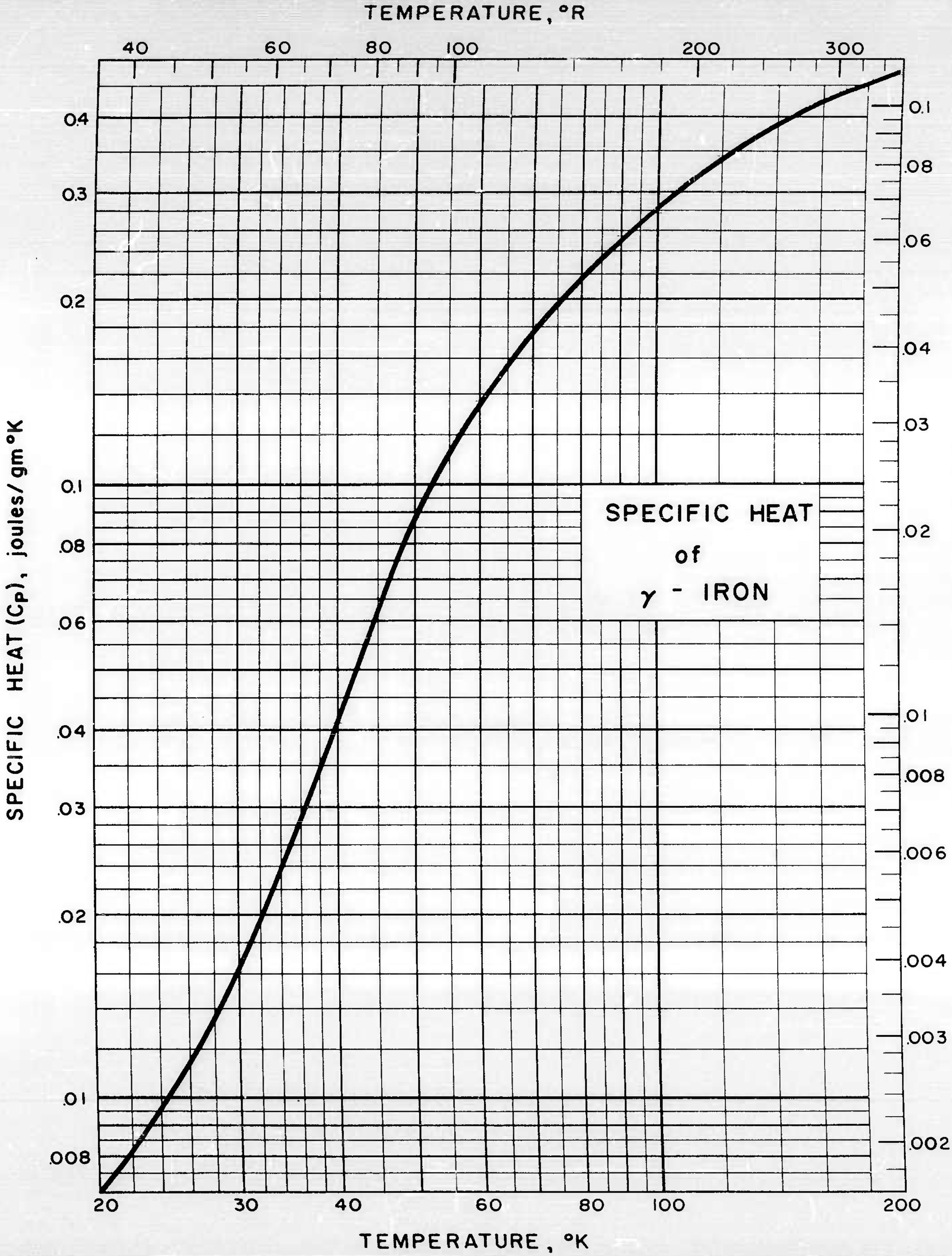
Eucken A. and Werth, H., Z. anorg. u. allgem. Chem. 188, 152-72 (1930).

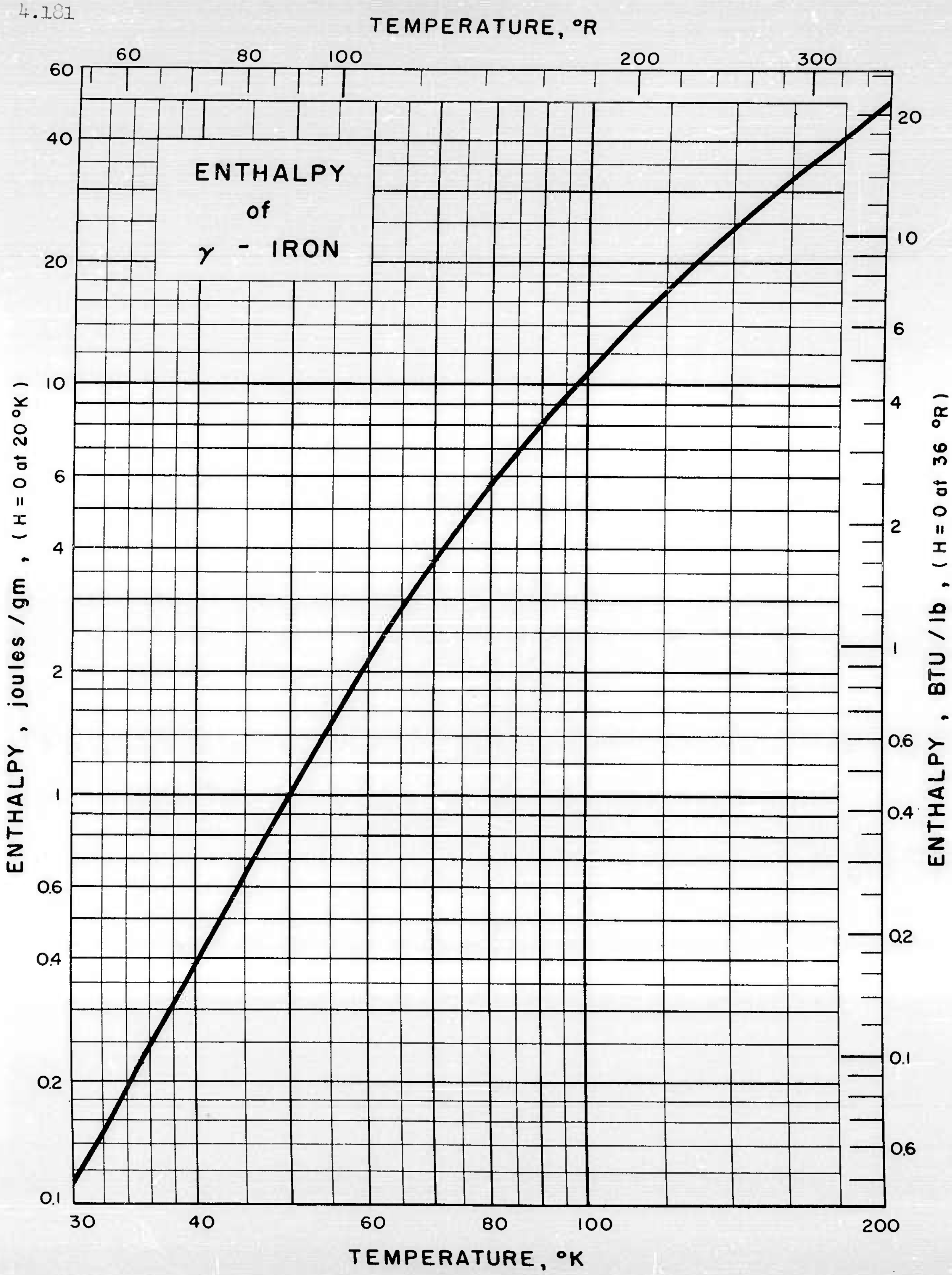
Comments:

The values of specific heat for pure γ iron were calculated by Eucken and Werth by application of the Kopp-Neumann principle to their specific heat measurements on a 30% Mn-Fe alloy and 19.4% Mn-Fe alloy. In view of this procedure, the values tabulated below should be regarded as an approximation only.

T °K	C_p j/gm-°K	$H-H_{20}$ j/gm
20	0.007	
30	.016	0.11
40	.041	0.39
50	.090	1.0_2
60	$.13_7$	2.1_6
70	$.18_0$	3.7_5
80	$.21_8$	5.7_4
90	$.25_5$	8.1_1
100	$.28_8$	10.8
120	$.34_5$	17.1
140	$.38_9$	24.4
160	$.42_7$	32.6
180	$.45_0$	41.4
200	$.47_0$	50.6

RJC/JJG Issued: 9-2-59


TEMPERATURE, °R
40
60
80
100
200
300
0.4
0.3
0.2
0.1
.08
.06
.04
.03
.02
.01
.008
0.1
.08
.06
.04
.03
.02
.01
.008
.006
.004
.003
.002
SPECIFIC HEAT (C_p), joules/gm°K
SPECIFIC HEAT (C_p), BTU/lb°R
SPECIFIC HEAT
of
γ - IRON
20
30
40
60
80
100
200
TEMPERATURE, °K


TEMPERATURE, °R
60
80
100
200
300
ENTHALPY
of
γ - IRON
ENTHALPY , joules / gm , (H = 0 at 20 °K)
60
40
20
10
6
4
2
1
0.6
0.4
0.2
0.1
ENTHALPY , BTU / lb , (H = 0 at 36 °R)
20
10
6
4
2
1
0.6
0.4
0.2
0.1
0.6
30
40
60
80
100
200
TEMPERATURE, °K

SPECIFIC HEAT and ENTHALPY of NICKEL

Sources of Data:

Busey, R. H. and Giauque, W. F., J. Am. Chem. Soc. 74, 3157-8 (1952)

Keesom, W. H. and Clark, C. W., Physica 2, 513-20 (1935)

Rayne, J. A. and Kemp, W. R. G., Phil. Mag. (8) 1, 918 (1956)

Other References:

Aoyama, S. and Kanda, E., J. Chem. Soc. Japan 62, 312-5 (1941)

Behn, U., Ann. Physik (3) 66, 237 (1898)

Bronson, H. L. and Wilson, A. J. C., Can. J. Research A14, 181 (1936)

Clusius, K. and Goldman, J., Z. physik. Chem. B31, 256 (1936)

Duyckaerts, G., Mem. soc. roy. sci. Liege 6, 193 (1945)

Eucken, A. and Werth, H., Z. anorg. u. allgem. Chem. 188, 152 (1930)

Grew, K. E., Prox. Roy. Soc. (London) A145, 509 (1934)

Keesom, W. H. and Kok, J. A., 7th Cong. intern. froid. 1st Comm. intern. Rapports et Commun., 156 (1936)

Lapp, E., Ann. Physik. 12, 442 (1929)

Richards, T. W. and Jackson, F. G., Z. physik. Chem. 70, 414 (1910)

Rodebush, W. H. and Michalek, J. C., J. Am. Chem. Soc. 47, 2117 (1925)

Schmitz, H. E., Proc. Roy. Soc. (London) 72, 177 (1903)

Simon, F. and Ruheman, M., Z. physik. Chem. 129, 321 (1927)

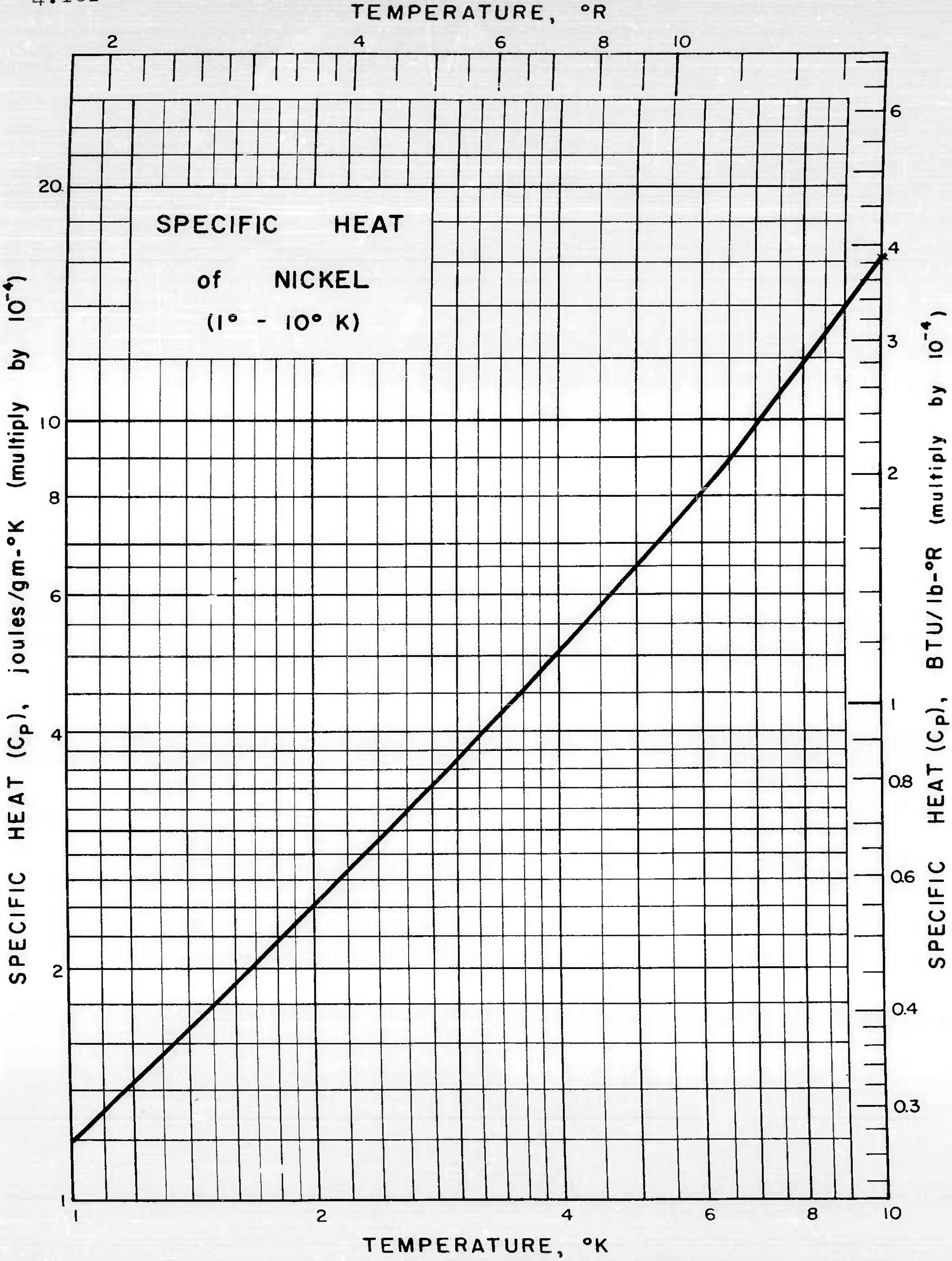
Tilden, W. A., Phil. Trans. Roy. Soc. London A194, 233 (1900); Proc. Roy. Soc. (London) 66, 244 (1900)

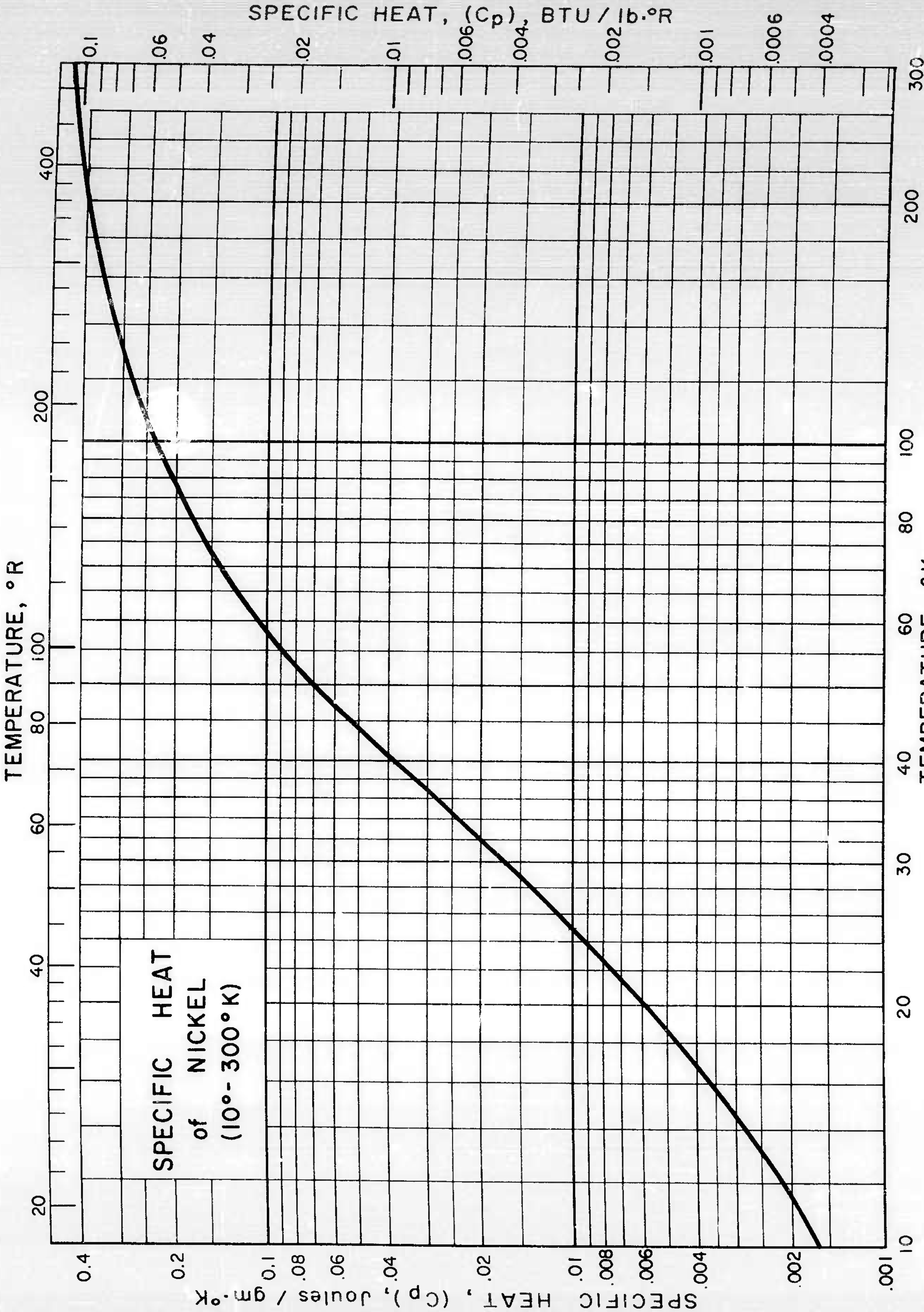
Table of Selected Values

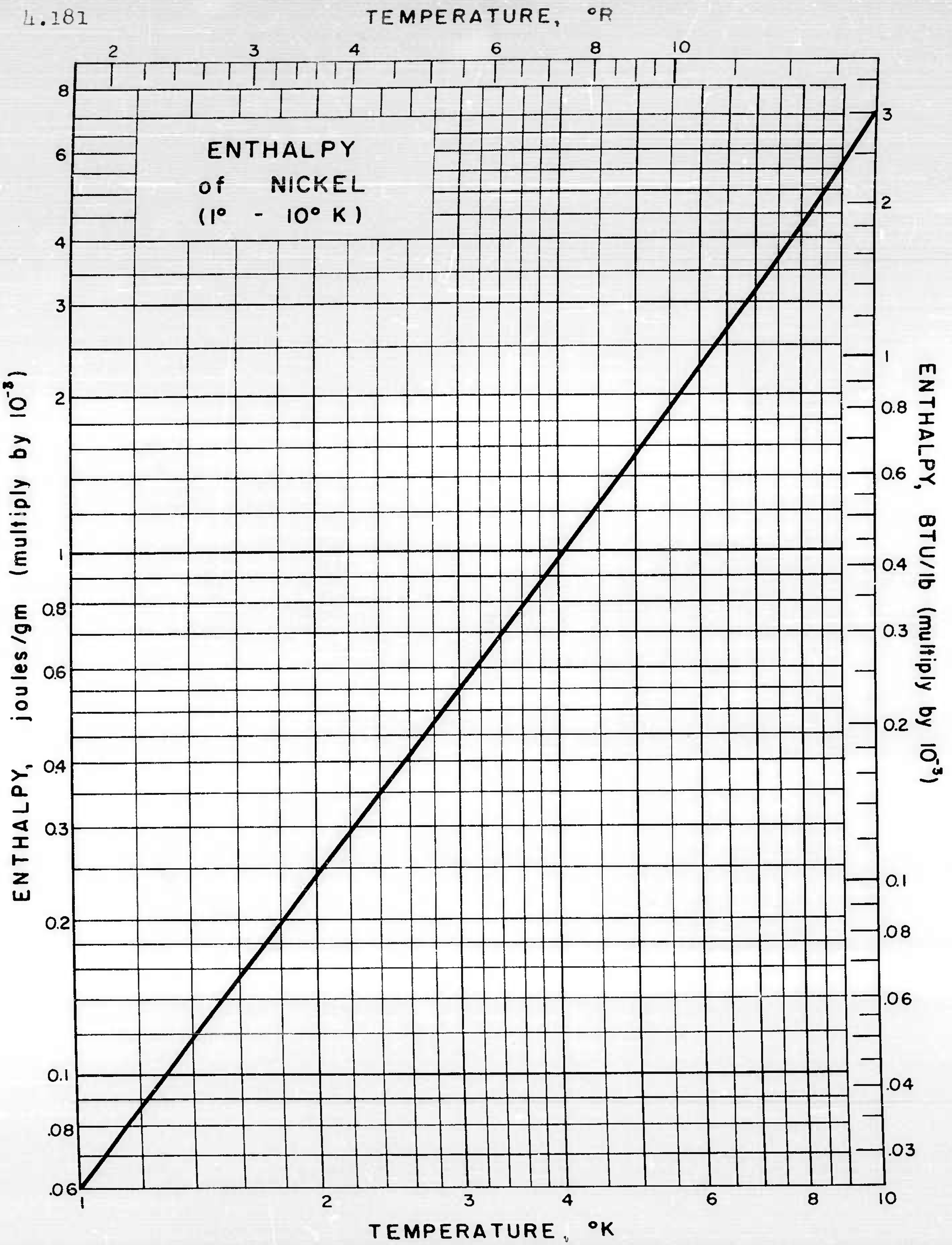
T °K	C_p j/gm-°K	H j/gm	T °K	C_p j/gm-°K	H j/gm
1	0.000 120	0.000 060	70	0.139	3.00
2	.000 242	.000 241	80	.173	4.56
3	.000 369	.000 546	90	.204	6.45
4	.000 503	.000 98	100	.232	8.63
6	.000 82	.002 28	120	.278	13.76
8	.001 19	.004 28	140	.314	19.70
10	.001 62	.007 1	160	.342	26.28
15	.003 1	.018 5	180	.365	33.35
20	.005 8	.041	200	.383	40.82
25	.010 1	.079	220	.397	48.6
30	.016 7	.145	240	.410	56.7
40	.038 1	.413	260	.422	65.0
50	.068 2	.937	280	.433	73.6
60	.103	1.79	300	.445	82.4

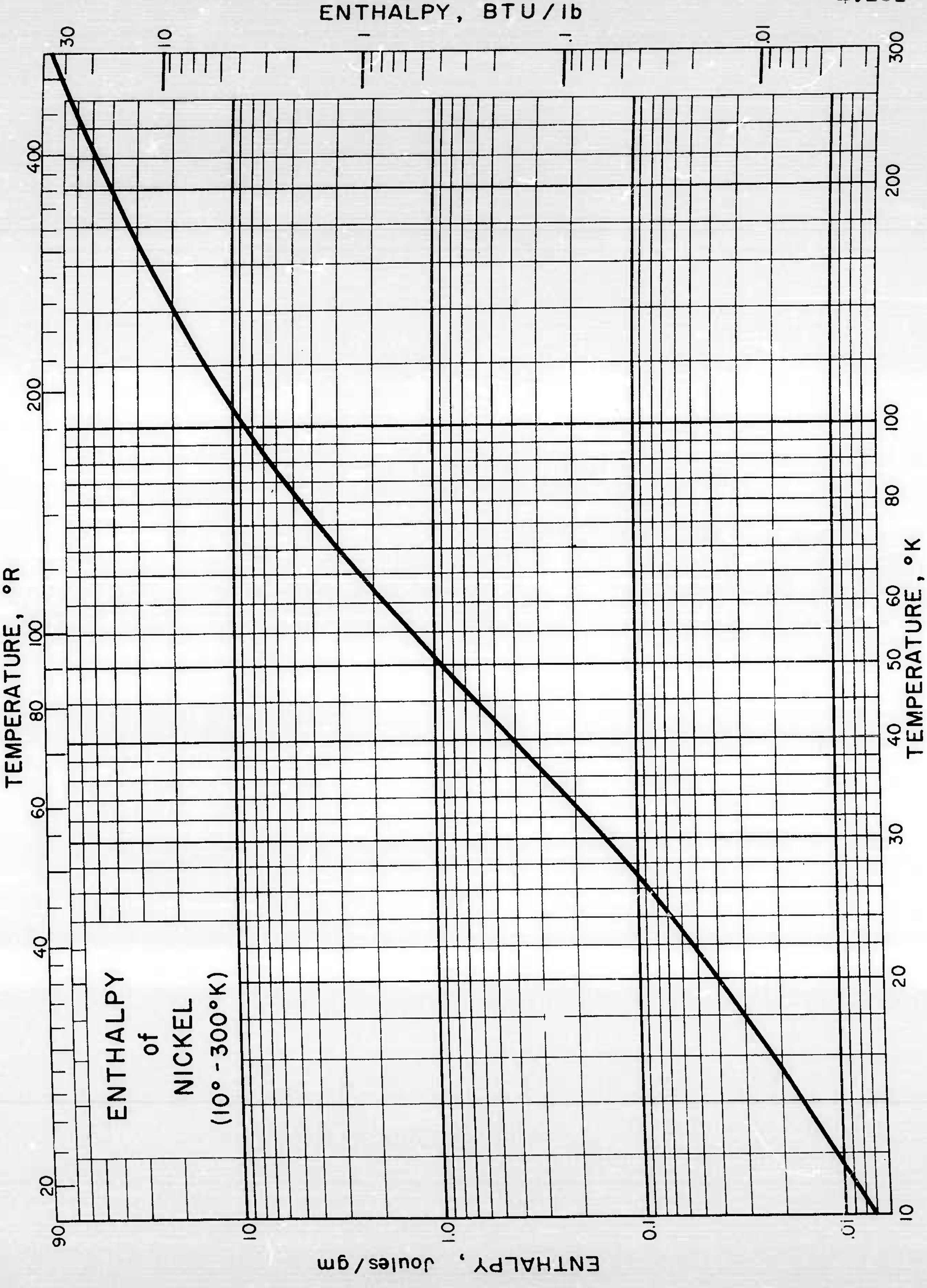
RJC Issued: 12-18-59

Revised: 5-20-60


TEMPERATURE, °R
2
4
6
8
10
SPECIFIC HEAT
of NICKEL
(1° - 10° K)
SPECIFIC HEAT (C_p), joules/gm-°K (multiply by 10^{-4})
20
10
8
6
4
2
1
SPECIFIC HEAT (C_p), BTU/lb-°R (multiply by 10^{-4})
6
4
3
2
1
0.8
0.6
0.4
0.3
1
2
4
6
8
10
TEMPERATURE, °K


SPECIFIC HEAT, (Cp), BTU / lb·°R
.1
.06
.04
.02
.01
.006
.004
.002
.001
.0006
.0004
TEMPERATURE, °R
20
40
60
80
100
200
400
TEMPERATURE, °K
10
20
30
40
60
80
100
200
300
SPECIFIC HEAT of NICKEL (10°- 300°K)
SPECIFIC HEAT, (Cp), Joules / gm·°K
0.4
0.2
0.1
.08
.06
.04
.02
.01
.008
.006
.004
.002
.001


TEMPERATURE, °R
2
3
4
6
8
10
ENTHALPY
of NICKEL
(1° - 10° K)
8
6
4
3
2
1
0.8
0.6
0.4
0.3
0.2
0.1
.08
.06
ENTHALPY, joules/gm (multiply by 10^{-3})
3
2
1
0.8
0.6
0.4
0.3
0.2
0.1
.08
.06
.04
.03
ENTHALPY, BTU/lb (multiply by 10^{-3})
1
2
3
4
6
8
10
TEMPERATURE, °K


ENTHALPY, BTU/lb
30
10
1
.1
.01
TEMPERATURE, °R
400
200
100
80
60
40
20
TEMPERATURE, °K
300
200
100
80
60
50
40
30
20
10
ENTHALPY of NICKEL (10° - 300°K)
ENTHALPY, Joules/gm
90
10
1.0
0.1
.01

SPECIFIC HEAT, ENTHALPY of PALLADIUM

Sources of Data:

Clusius, K. and Schachinger, L., Z. Naturforsch. 2a, 90-7 (1947)

Hoare, F. E. and Yates, B., Proc. Roy. Soc.(London) A240, 42-53, (1957)

Pickard, G. L. and Simon, F., Proc. Phys. Soc. (London) 61, 1-9, (1948)

Rayne, J. A., Phys. Rev. 95, 1428 (1954)

Other References:

Behn, U., Ann. Physik 66, 237 (1898)

Pickard, G. L., Nature 138, 123 (1936)

Richards, T. W. and Jackson, F. G., Z. physik. Chem. 70, 414 (1910)

Comments:

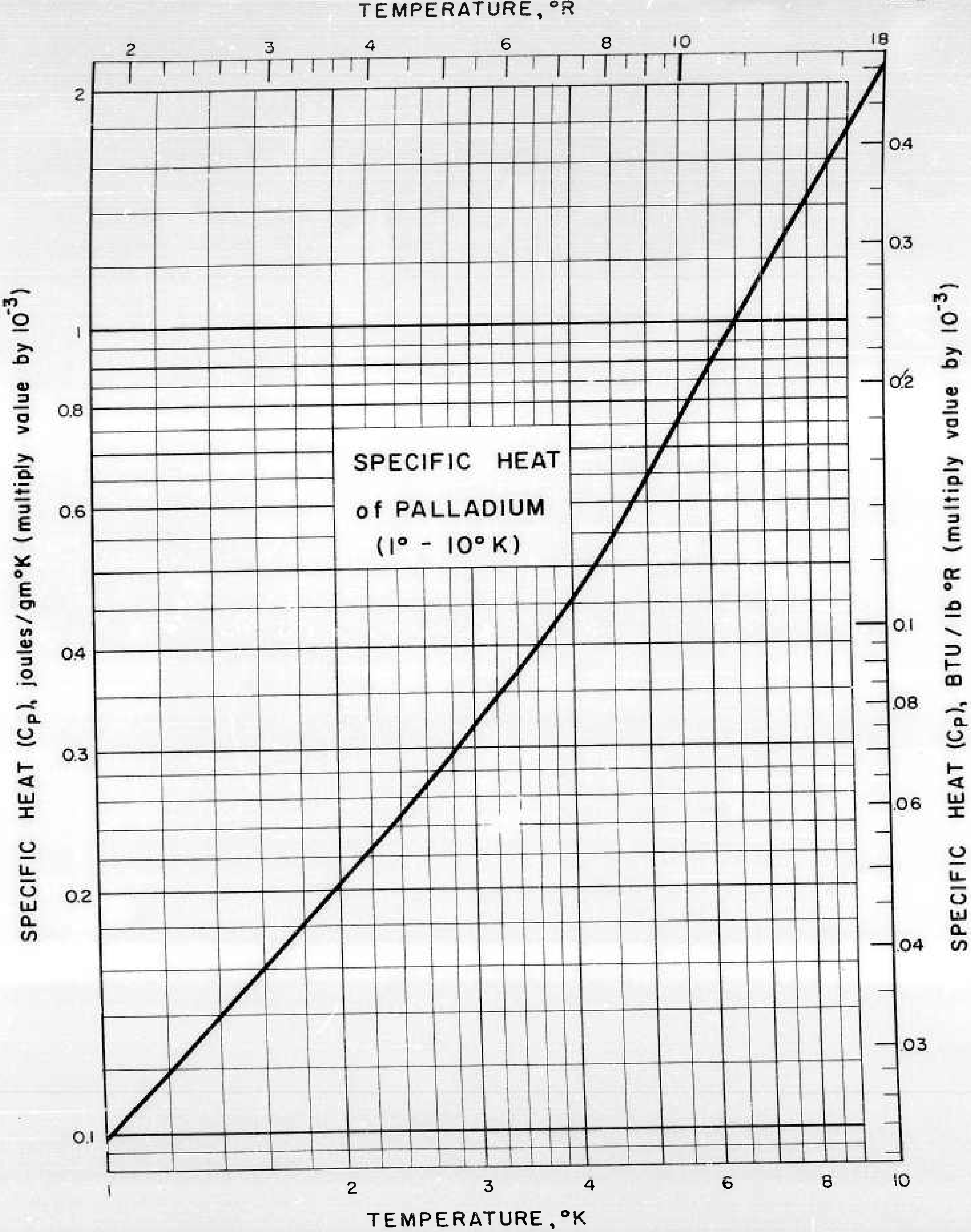
For the range from 0° to 4°K, the specific heat C_p follows the equation:

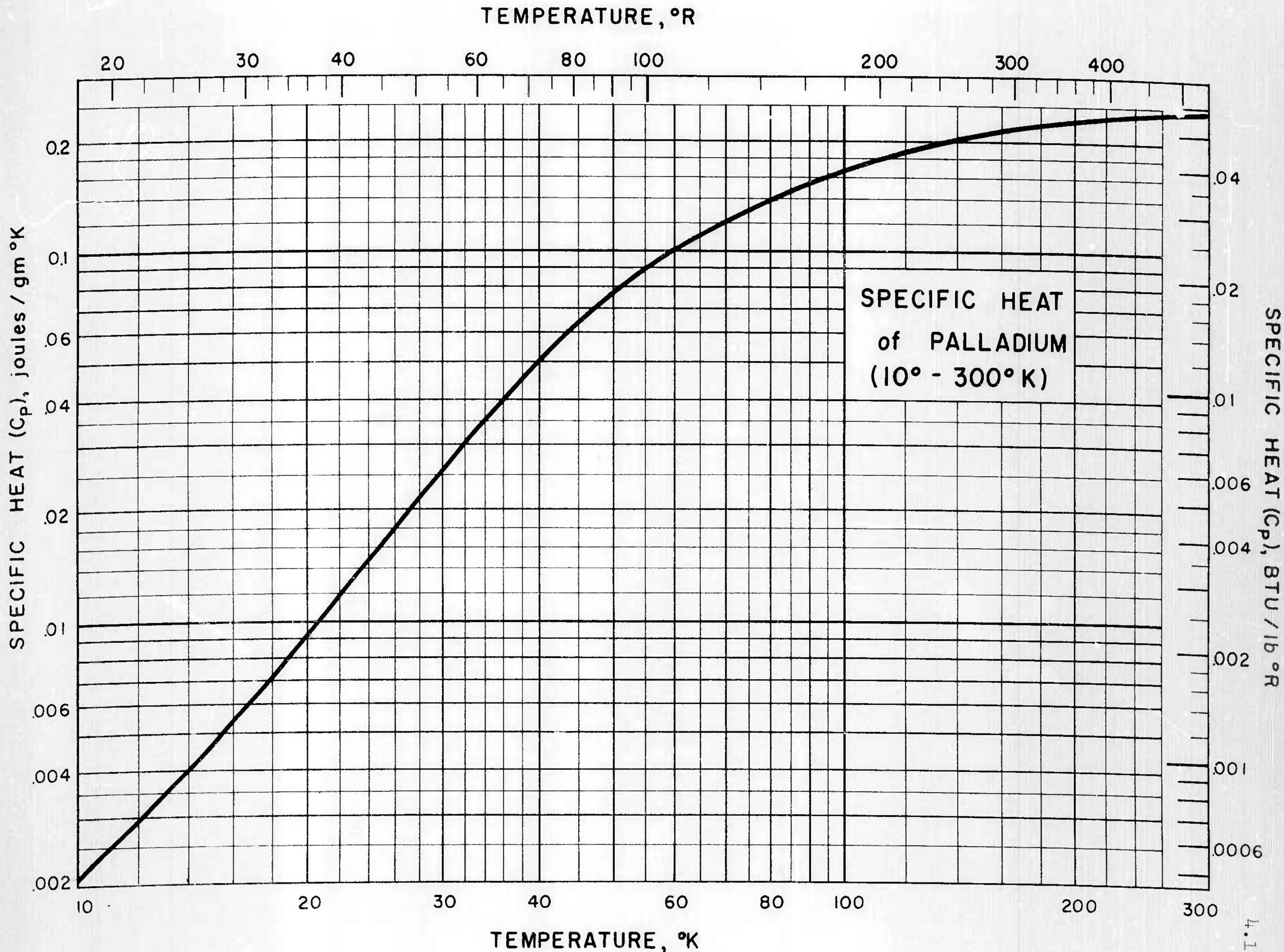
$$C_p = (9.8 \pm 0.8) \times 10^{-5} T + 18.22 \left(\frac{T}{274 \pm 3} \right)^3 \text{ j/gm-°K}$$

Table of Selected Values

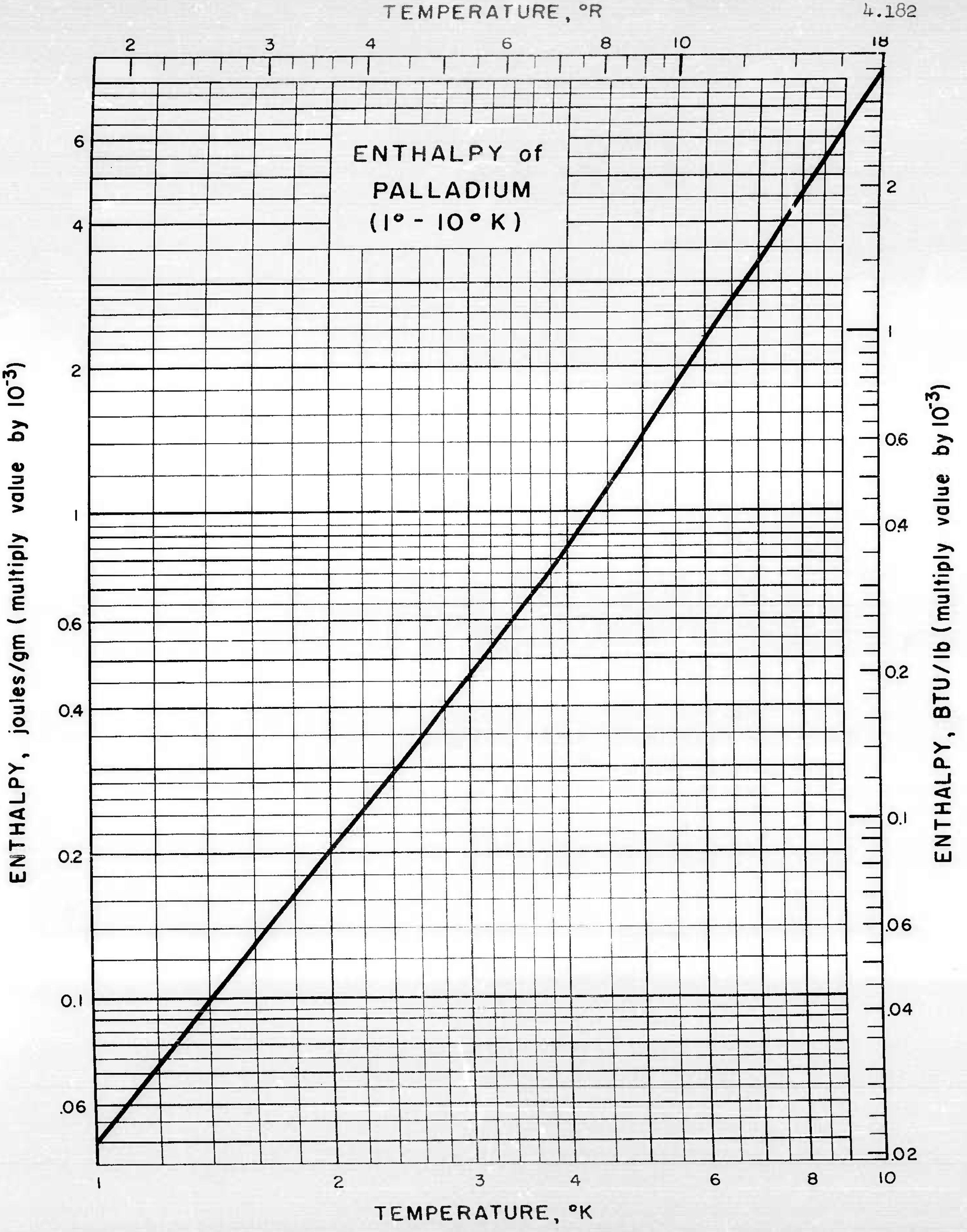
Temp. °K	C_p j/gm-°K	H j/gm	Temp. °K	C_p j/gm-°K	H j/gm
1	0.000 099	0.000 0493	70	0.122	3.26
2	.000 203	.000 200	80	.139	4.56
3	.000 318	.000 459	90	.154	6.03
4	.000 447	.000 840	100	.167	7.63
6	.000 891	.002 31	120	.188	11.2
8	.001 41	.004 60	140	.202	15.1
10	.002 10	.008 07	160	.213	19.2
15	.004 71	.024 5	180	.221	23.6
20	.009 22	.058 6	200	.227	28.1
25	.016 0	.120	220	.232	32.6
30	.025 8	.223	240	.236	37.3
40	.050 7	.600	260	.239	42.1
50	.077 7	1.24	280	.241	46.9
60	.101	2.14	300	.243	51.7

RJC/JJG Issued: 12-18-59

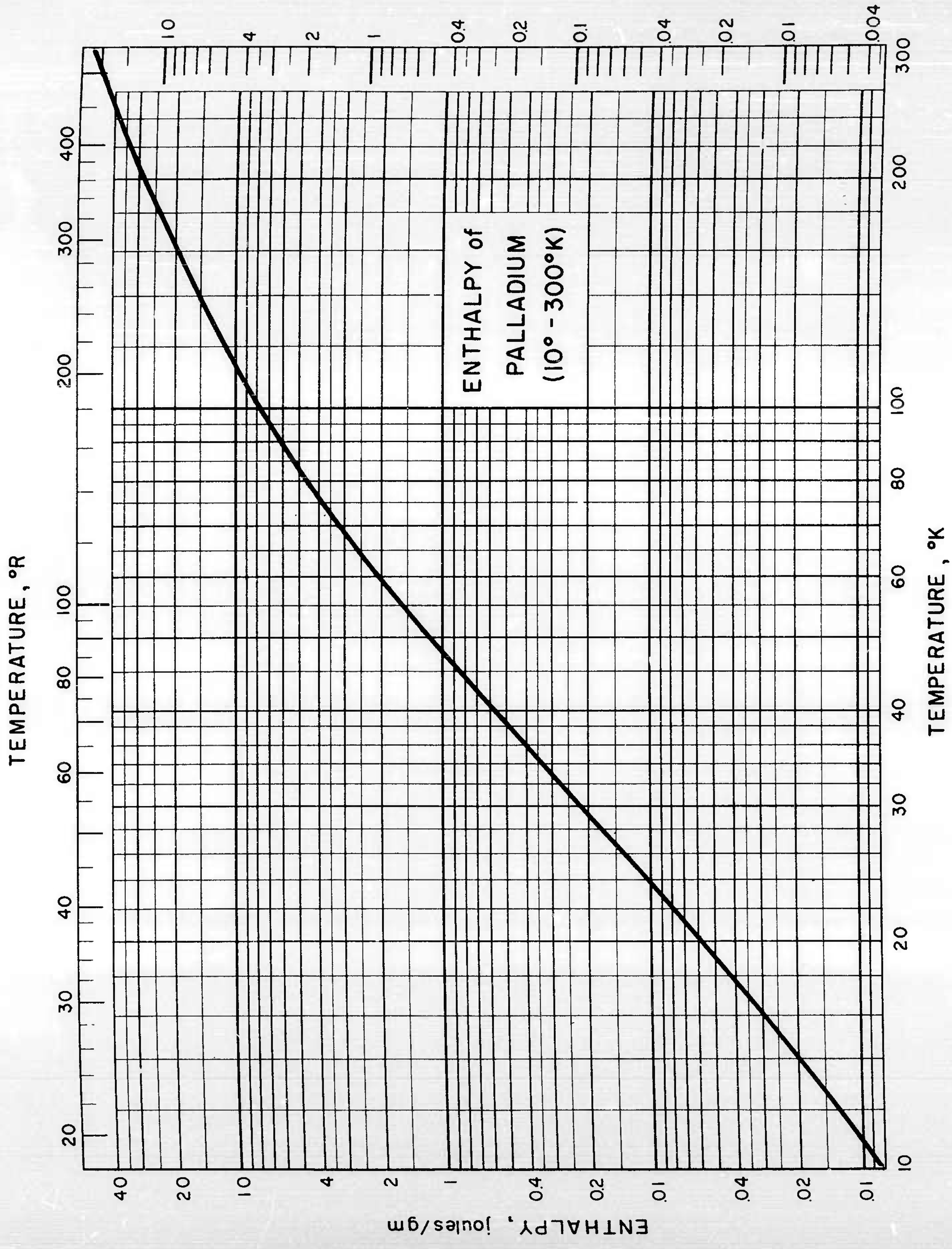

TEMPERATURE, °R
2
3
4
6
8
10
18
SPECIFIC HEAT
of PALLADIUM
(1° - 10° K)
SPECIFIC HEAT (C_p), joules/gm°K (multiply value by 10^{-3})
2
1
0.8
0.6
0.4
0.3
0.2
0.1
SPECIFIC HEAT (C_p), BTU / lb °R (multiply value by 10^{-3})
0.4
0.3
0.2
0.1
.08
.06
.04
.03
1
2
3
4
6
8
10
TEMPERATURE, °K


TEMPERATURE, °R
20
30
40
60
80
100
200
300
400
SPECIFIC HEAT (Cp), joules / gm °K
0.2
0.1
.06
.04
.02
.01
.006
.004
.002
SPECIFIC HEAT
of PALLADIUM
(10° - 300° K)
SPECIFIC HEAT (Cp), BTU / lb °R
.04
.02
.01
.006
.004
.002
.001
.0006
10
20
30
40
60
80
100
200
300
TEMPERATURE, °K

4.182



TEMPERATURE, °R
2
3
4
6
8
10
18
ENTHALPY of
PALLADIUM
(1° - 10° K)
ENTHALPY, joules/gm (multiply value by 10^{-3})
6
4
2
1
0.6
0.4
0.2
0.1
.06
ENTHALPY, BTU/lb (multiply value by 10^{-3})
2
1
0.6
0.4
0.2
0.1
.06
.04
.02
1
2
3
4
6
8
10
TEMPERATURE, °K


ENTHALPY, BTU/lb
ENTHALPY of PALLADIUM (10° - 300°K)
TEMPERATURE, °R
TEMPERATURE, °K
ENTHALPY, joules/gm
10 4 2 1 0.4 0.2 0.1 0.04 0.2 0.01 0.004
300 200 100 80 60 40 30 20 10
400 300 200 100 80 60 40 30 20
40 20 10 4 2 1 0.4 0.2 0.1 0.4 0.2 0.1

SPECIFIC HEAT, ENTHALPY of PLATINUM

Sources of Data:

Kok, J. A. and Keesom, W. H., Physica 3, 1035-45 (1936)

Ramanathan, K. G. and Srinivasan, T. M., Proc. Indian Acad. Sci. 49, 55-60 (1959)

Simon, F. and Zeidler, W., Z. physik. Chem. 123, 383 (1926)

Other References:

Behn, U., Ann. Physik. 66, 237 (1898)

Rayne, J. A., Phys. Rev. 95, 1428 (1954)

Richards, T. W. and Jackson, F. G., Z. physik. Chem. 70, 414 (1910)

Tilden, W. A., Proc. Roy. Soc. (London) A71, 220 (1903); Ann. Physik. Beiblätter 27, 557 (1903)

Comments:

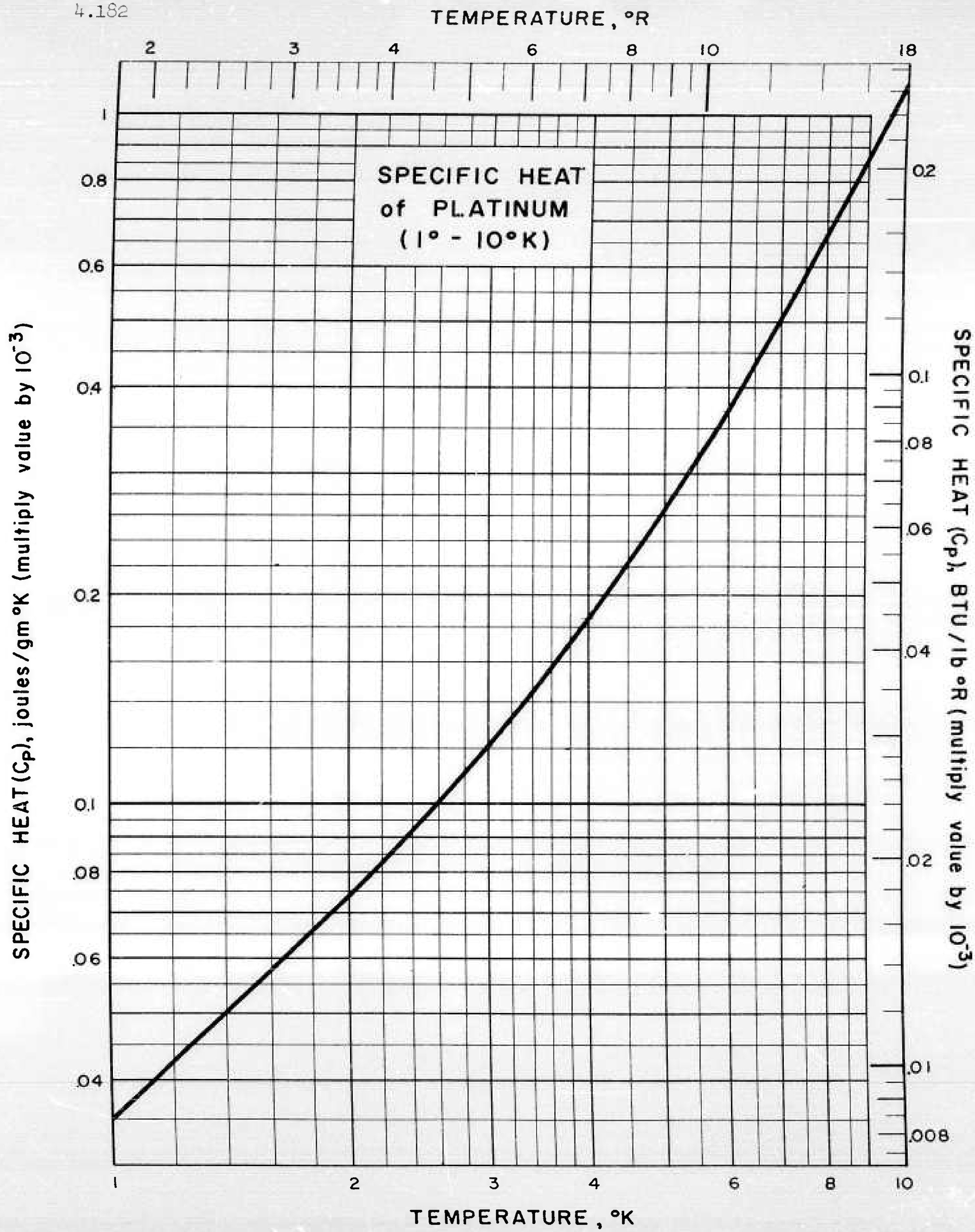
For the temperature range from 0° to 3°K, the specific heat C_p follows the equation:

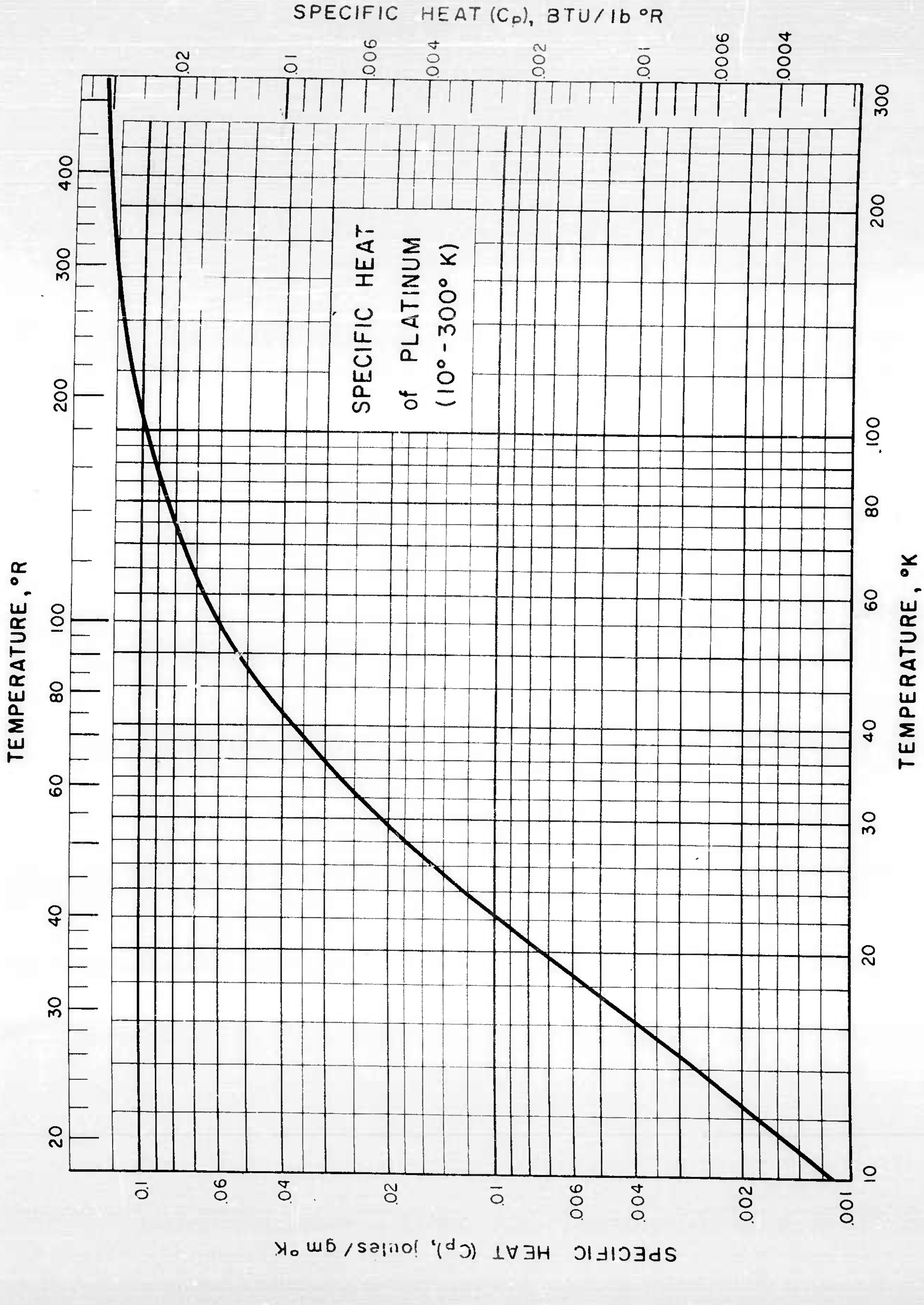
$$C_p = (3.41 \pm 0.02) \times 10^{-5} T + 9.96 \left(\frac{T}{240 \pm 5} \right)^3 \text{ j/gm-°K}$$

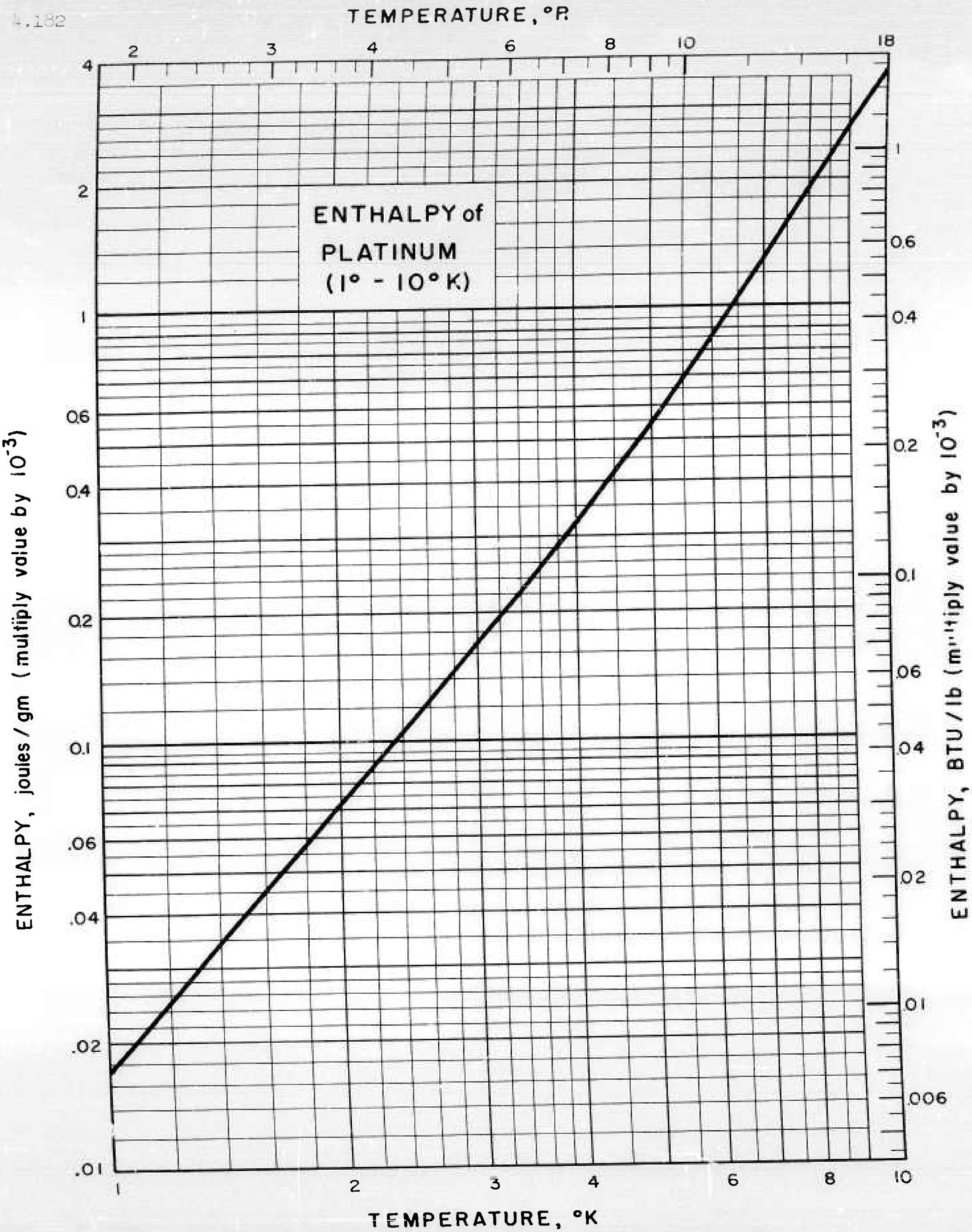
Table of Selected Values

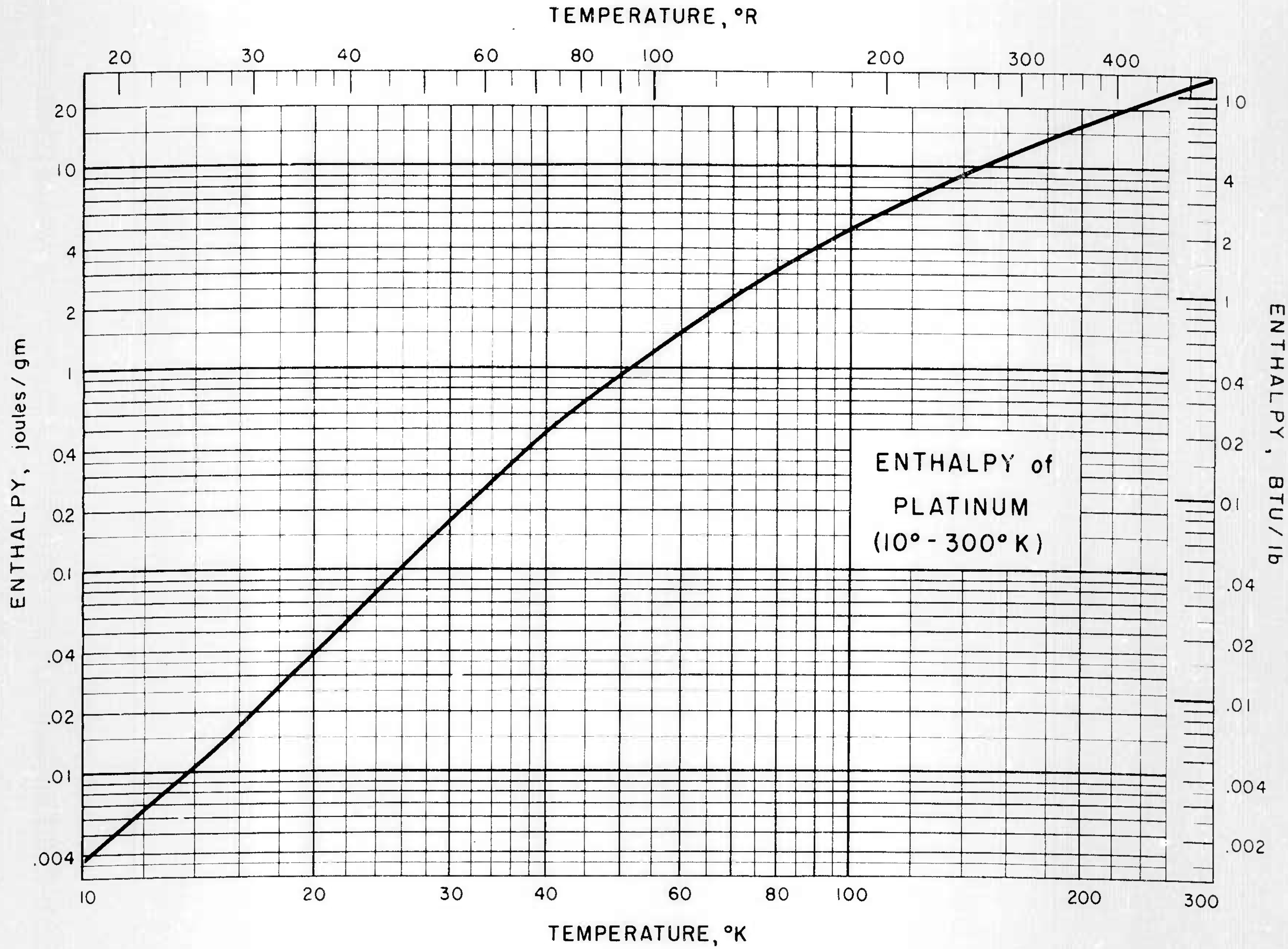
Temp. °K	C_p j/gm-°K	H j/gm	Temp. °K	C_p j/gm-°K	H j/gm
1	0.000 035	0.000 0175	70	0.079	2.29
2	.000 074	.000 071	80	.088	3.12
3	.000 122	.000 168	90	.094	4.02
4	.000 186	.000 320	100	.100	5.01
6	.000 37	.000 85	120	.109	7.10
8	.000 67	.001 88	140	.116	9.37
10	.001 12	.003 65	160	.121	11.8
15	.003 3	.013 5	180	.125	14.2
20	.007 4	.039 5	200	.127	16.7
25	.013 7	.092	220	.129	19.3
30	.021 2	.182	240	.130	21.9
40	.038	.48	260	.131	24.5
50	.055	.95	280	.132	27.1
60	.068	1.56	300	.133	29.8

RJC/JJG Issued: 12-18-59
Revised: 5-20-60


TEMPERATURE, °R
2
3
4
6
8
10
18
SPECIFIC HEAT
of PLATINUM
(1° - 10°K)
1
0.8
0.6
0.4
0.2
0.1
.08
.06
.04
SPECIFIC HEAT (C_p), joules/gm °K (multiply value by 10^{-3})
.2
0.1
.08
.06
.04
.02
.01
.008
SPECIFIC HEAT (C_p), BTU/lb °R (multiply value by 10^{-3})
1
2
3
4
6
8
10
TEMPERATURE, °K


SPECIFIC HEAT (Cp), BTU/lb °R
.02
.01
.006
.004
.002
.001
.0006
.0004
SPECIFIC HEAT
of PLATINUM
(10° - 300° K)
TEMPERATURE, °R
400
300
200
100
80
60
40
30
20
TEMPERATURE, °K
300
200
100
80
60
40
30
20
10
.1
.06
.04
.02
.01
.006
.004
.002
.001
SPECIFIC HEAT (Cp), joules/gm °K


TEMPERATURE, °R
2
3
4
6
8
10
18
ENTHALPY of PLATINUM (1° - 10° K)
ENTHALPY, joules / gm (multiply value by 10^{-3})
4
2
1
0.6
0.4
0.2
0.1
.06
.04
.02
.01
ENTHALPY, BTU / lb (multiply value by 10^{-3})
1
0.6
0.4
0.2
0.1
.06
.04
.02
.01
.006
1
2
3
4
6
8
10
TEMPERATURE, °K



TEMPERATURE, °R
20
30
40
60
80
100
200
300
400
ENTHALPY of
PLATINUM
(10° - 300° K)
ENTHALPY, joules / gm
20
10
4
2
1
0.4
0.2
0.1
.04
.02
.01
.004
ENTHALPY, BTU / lb
10
4
2
1
0.4
0.2
0.1
.04
.02
.01
.004
.002
10
20
30
40
60
80
100
200
300
TEMPERATURE, °K

SPECIFIC HEAT, ENTHALPY of RHODIUM

Source of Data:

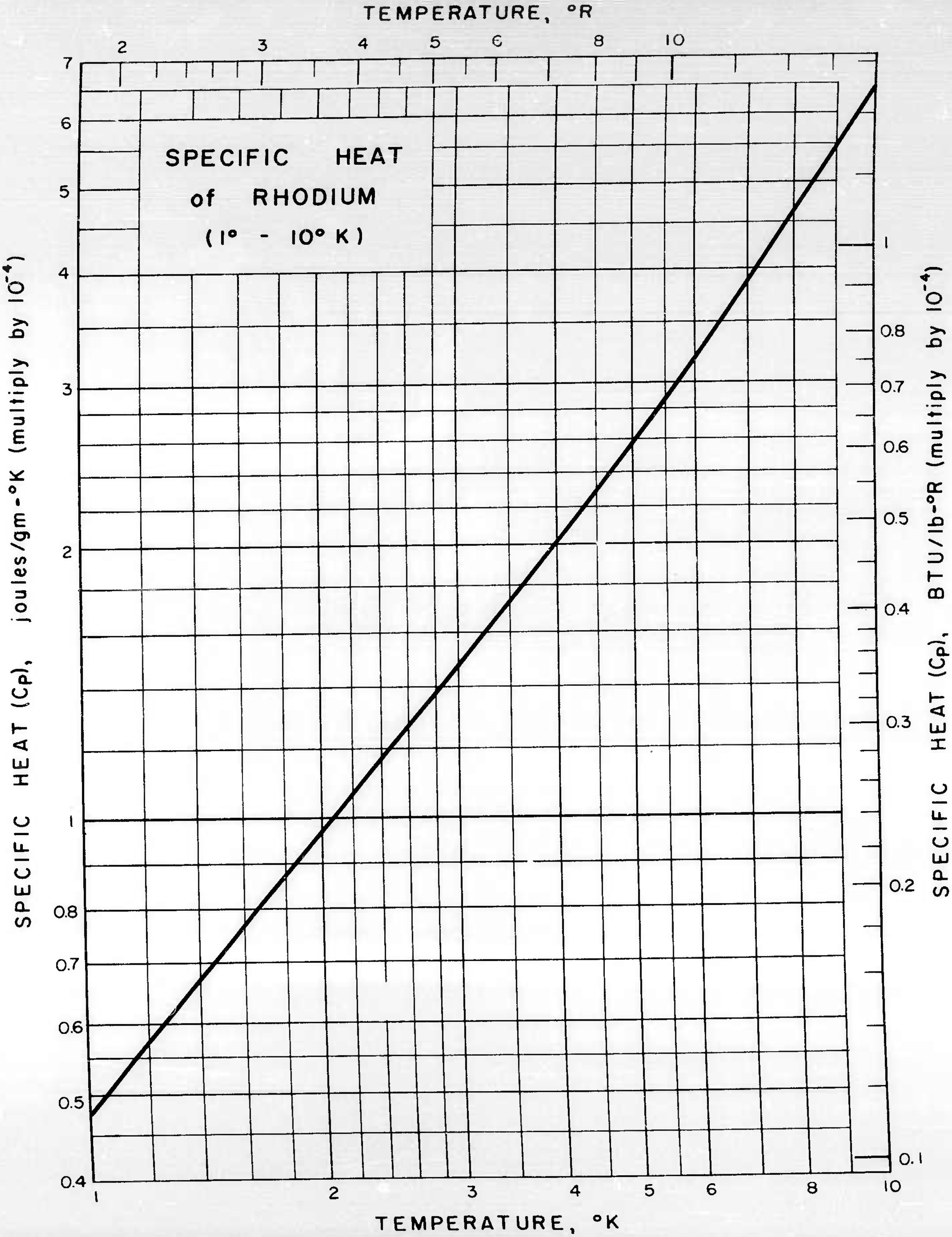
Clusius, K., and Losa, C. G., Z. Naturforsch. 10A, 545 (1955)

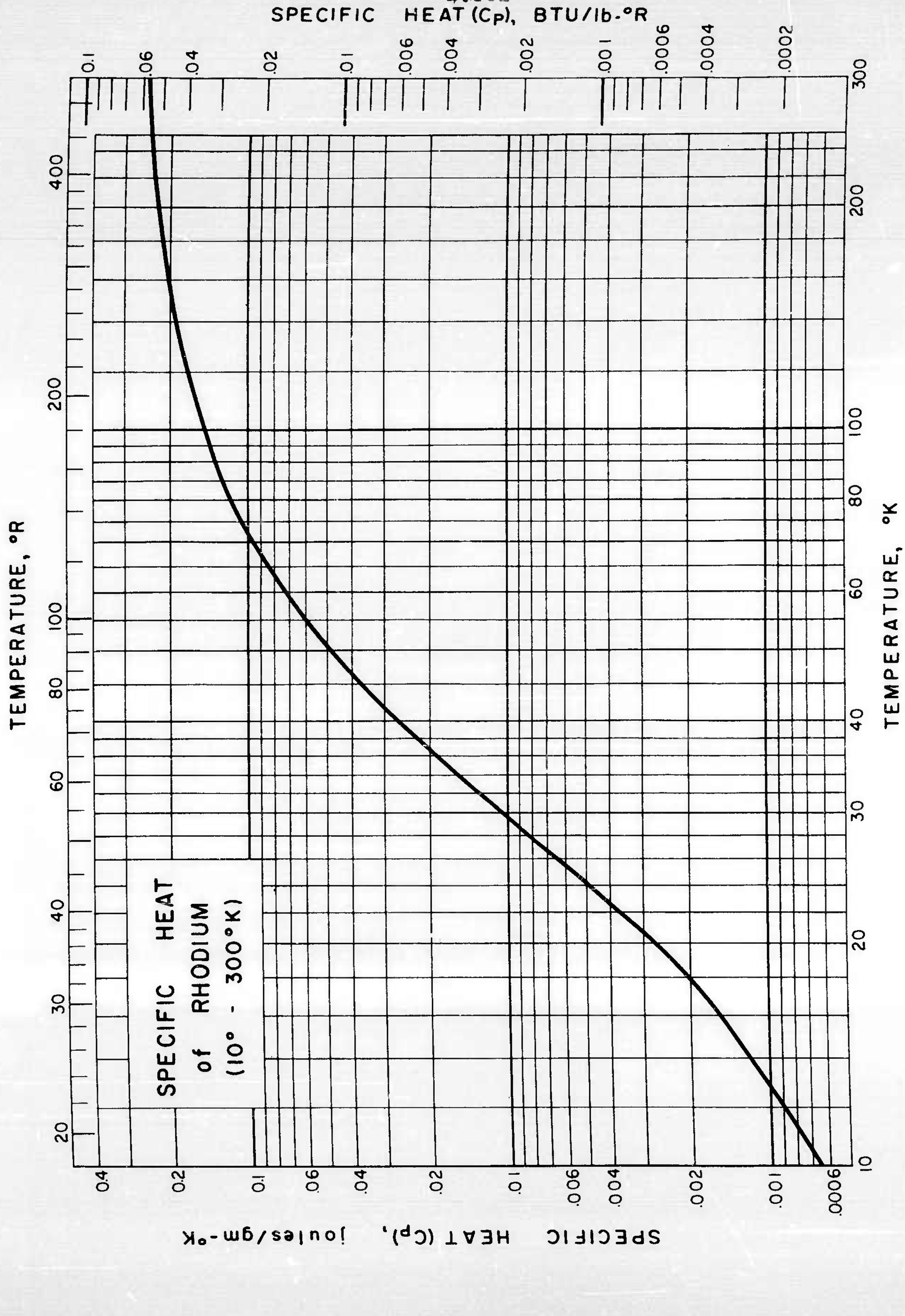
Wolcott, N. M., Conf. Phys. basses Temp. (1955)

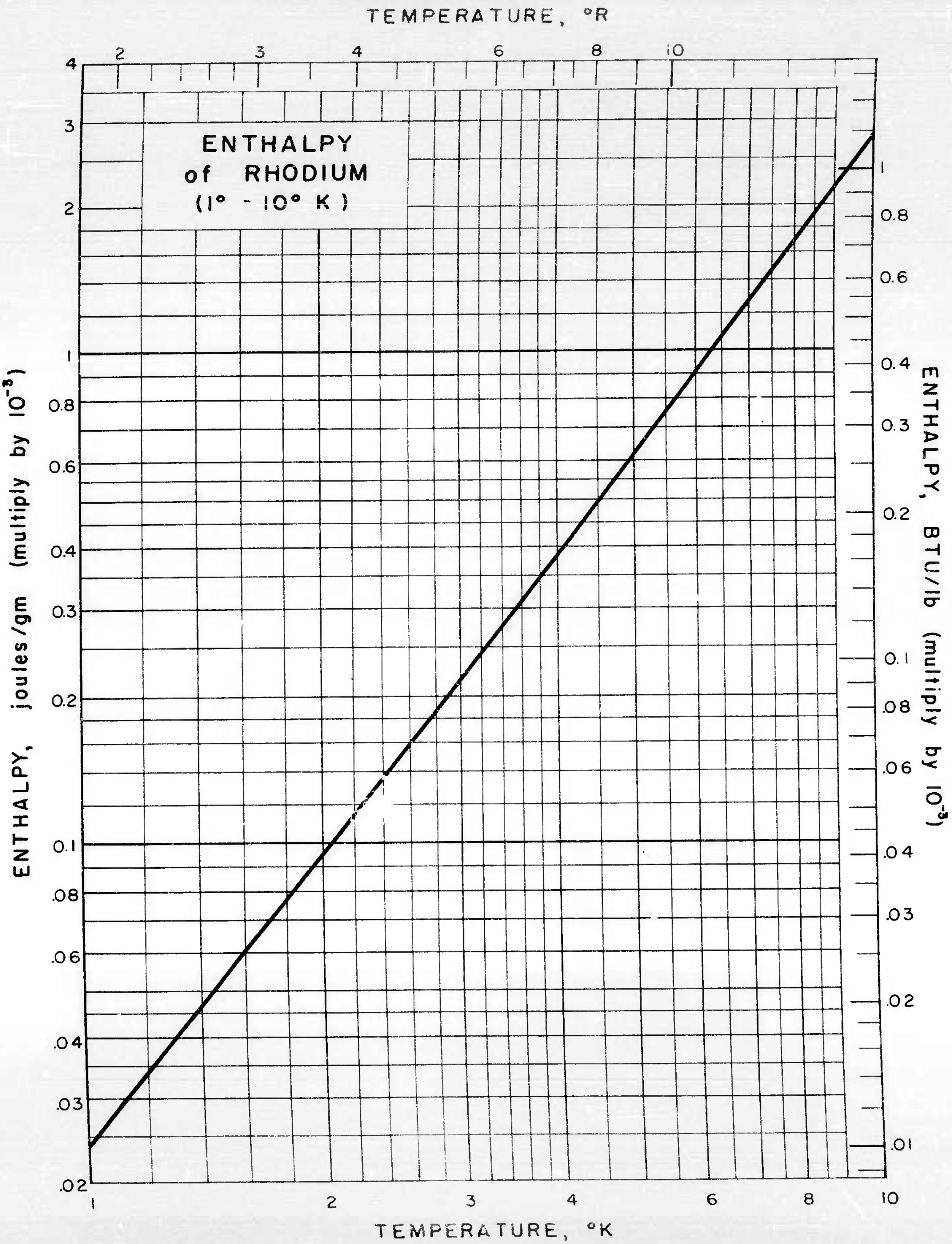
Table of Selected Values

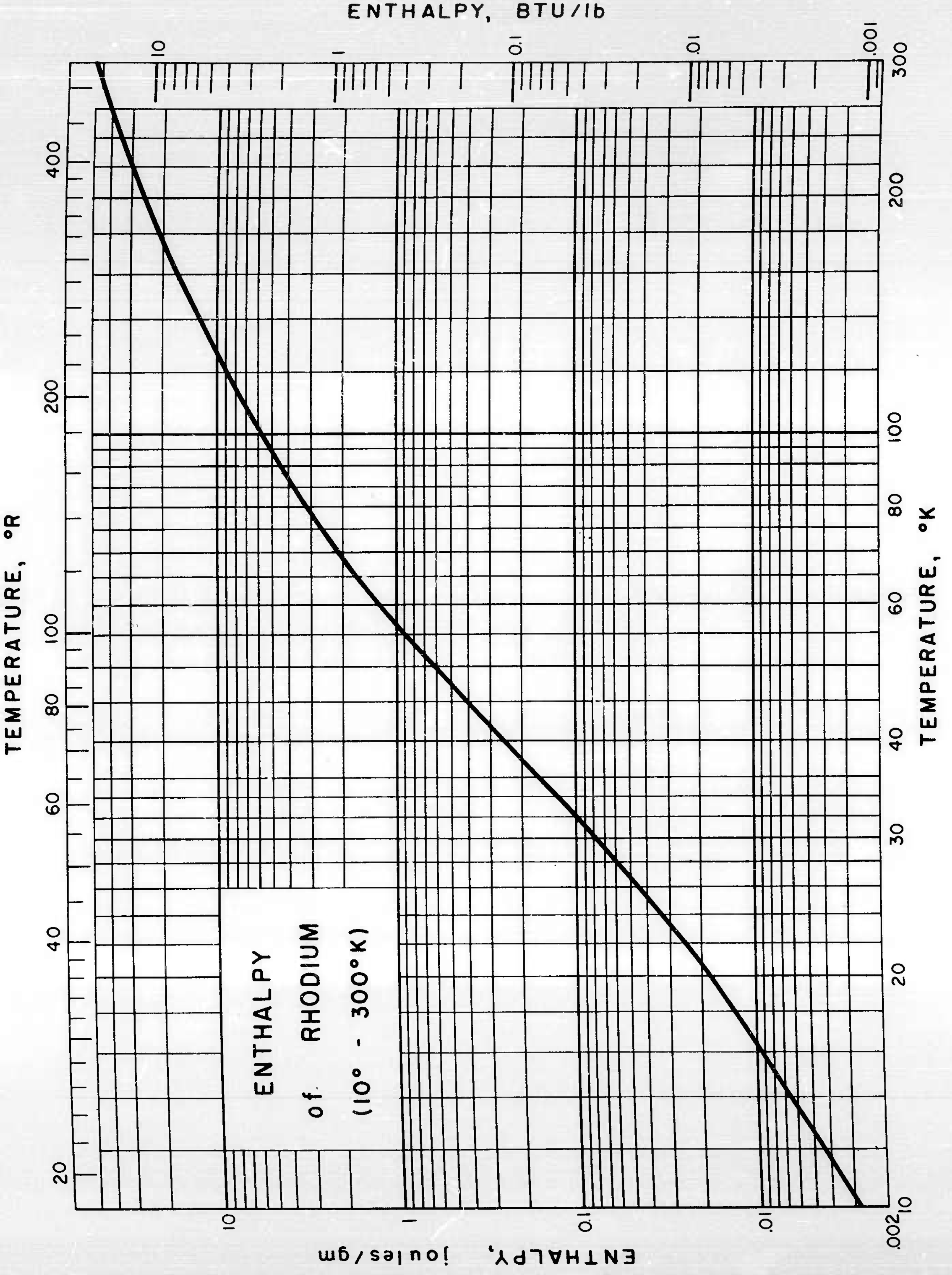
T °K	Cp j/gm-°K	H j/gm	T °K	Cp j/gm-°K	H j/gm
1	0.000 048	0.000 024	70	0.094	2.07
2	.000 097	.000 096	80	.114	3.11
3	.000 147	.000 218	90	.132	4.34
4	.000 201	.000 392	100	.147	5.74
6	.000 32	.000 91	120	.171	8.93
8	.000 47	.001 70	140	.189	12.54
10	.000 65	.002 81	160	.202	16.46
15	.001 35	.007 65	180	.212	20.60
20	.002 71	.017 4	200	.220	24.92
25	.005 61	.037 3	220	.226	29.38
30	.010 6	.077 1	240	.232	33.96
40	.026 6	.256	260	.236	38.63
50	.048 9	.633	280	.240	43.38
60	.072 4	1.238	300	.243	48.2

RJC/jrc Issued: 6-5-59


TEMPERATURE, °R
2
3
4
5
6
8
10
SPECIFIC HEAT
of RHODIUM
(1° - 10° K)
SPECIFIC HEAT (C_p), joules/gm-°K (multiply by 10^{-4})
7
6
5
4
3
2
1
0.8
0.7
0.6
0.5
0.4
SPECIFIC HEAT (C_p), BTU/lb-°R (multiply by 10^{-4})
1
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
1
2
3
4
5
6
8
10
TEMPERATURE, °K


SPECIFIC HEAT (Cp), BTU/lb-°R
SPECIFIC HEAT (Cp), joules/gm-°K
TEMPERATURE, °R
TEMPERATURE, °K
SPECIFIC HEAT of RHODIUM (10° - 300°K)


TEMPERATURE, °R
2
3
4
6
8
10
ENTHALPY
of RHODIUM
(1° - 10° K)
4
3
2
1
0.8
0.6
0.4
0.3
0.2
0.1
.08
.06
.04
.03
.02
ENTHALPY, joules/gm (multiply by 10^-3)
1
0.8
0.6
0.4
0.3
0.2
0.1
.08
.06
.04
.03
.02
.01
ENTHALPY, BTU/lb (multiply by 10^-3)
1
2
3
4
6
8
10
TEMPERATURE, °K


ENTHALPY, BTU/lb
10
1
0.1
.01
.001
TEMPERATURE, °R
400
200
100
80
60
40
20
TEMPERATURE, °K
300
200
100
80
60
40
30
20
10
ENTHALPY
of RHODIUM
(10° - 300°K)
10
1
0.1
.01
.002
ENTHALPY, joules/gm

SPECIFIC HEAT, ENTHALPY of WOOD'S METAL

(Sn, 12.5%; Cd, 12.5%; Pb, 25%; Bi, 50%)

Source of Data:

Parkinson, D. H. and Quarrington, J. E., Brit. J. Appl. Phys. 5, 219-20 (1954)

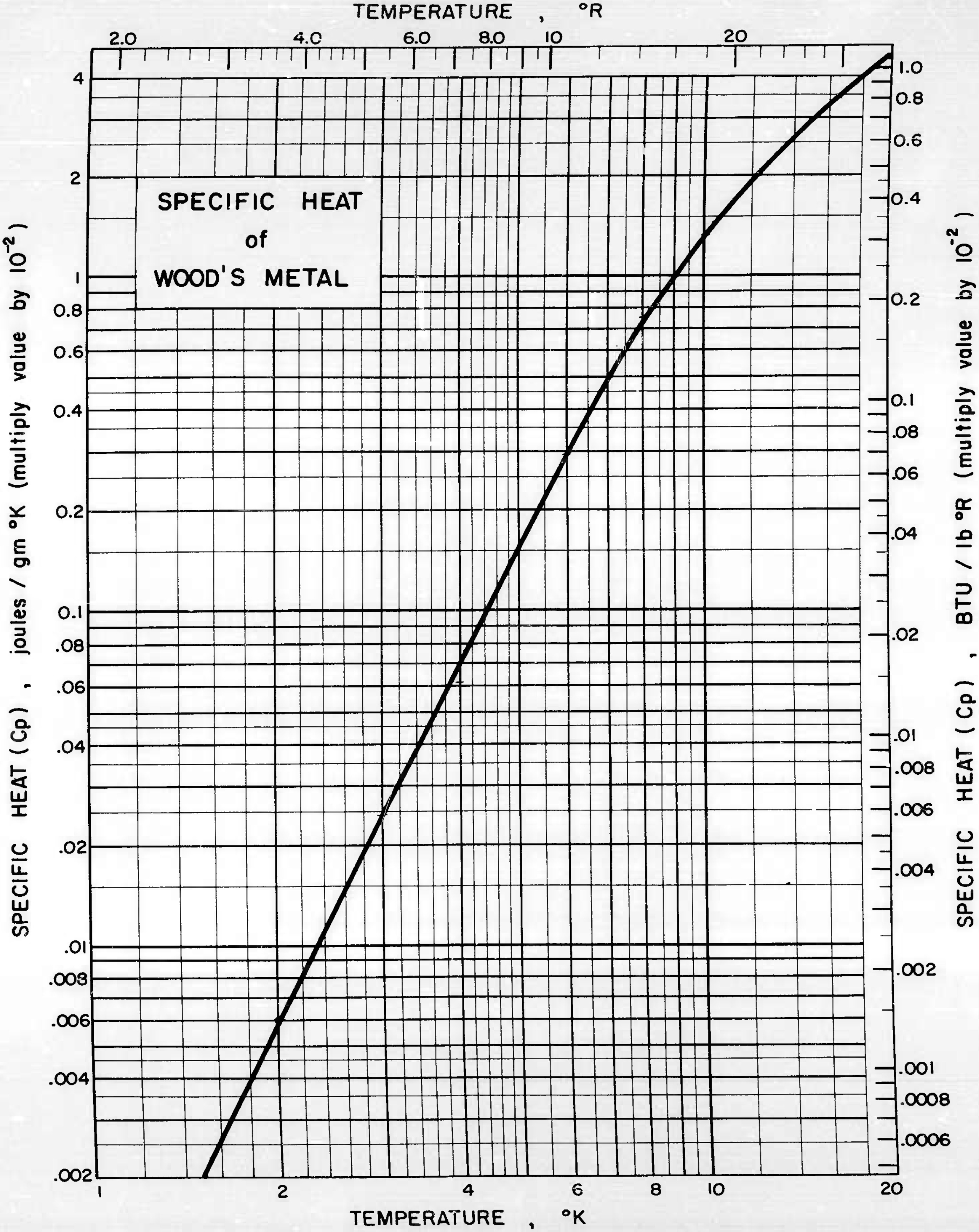
Comments:

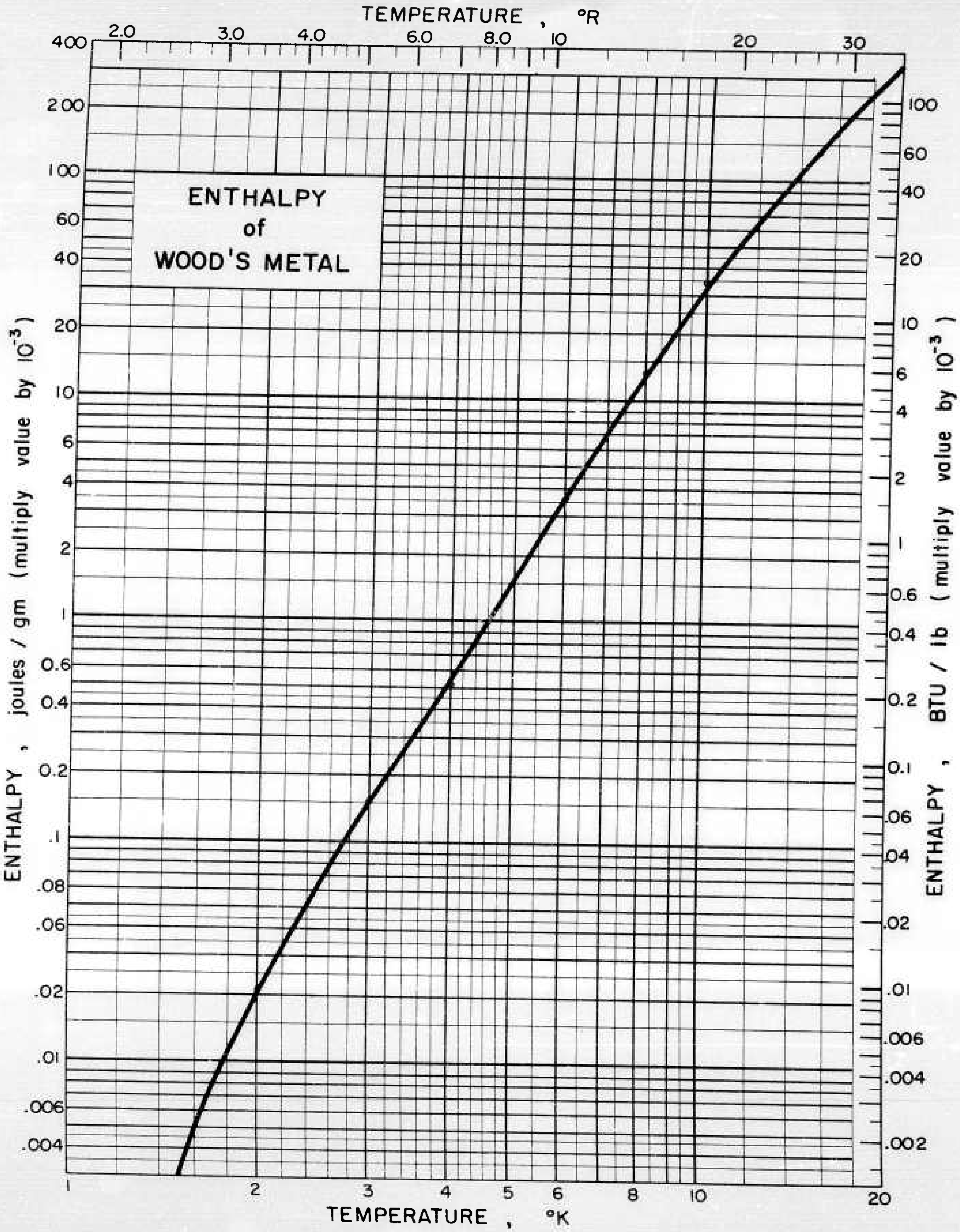
There was slight evidence of a superconducting transition at approximately 4.8°K. Tabulated values below 6°K are from measurements made in the superconducting state.

Table of Selected Values

Temp. °K	C_p j/gm-°K	H j/gm
1.5	0.000 02	0.000 003
2	.000 06	.000 022
3	.000 24	.000 154
4	.000 62	.000 516
6	.002 9	.003 57
8	.007 6	.013 8
10	.013 4	.034 7
15	.029 7	.142
20	.046 0	.331

RJC/VDA Issued: 12-14-59


TEMPERATURE , °R
2.0
4.0
6.0
8.0
10
20
SPECIFIC HEAT
of
WOOD'S METAL
SPECIFIC HEAT (Cp) , joules / gm °K (multiply value by 10^{-2})
4
2
1
0.8
0.6
0.4
0.2
0.1
.08
.06
.04
.02
.01
.008
.006
.004
.002
SPECIFIC HEAT (Cp) , BTU / lb °R (multiply value by 10^{-2})
1.0
0.8
0.6
0.4
0.2
0.1
.08
.06
.04
.02
.01
.008
.006
.004
.002
.001
.0008
.0006
1
2
4
6
8
10
20
TEMPERATURE , °K


TEMPERATURE , °R
2.0
3.0
4.0
6.0
8.0
10
20
30
ENTHALPY
of
WOOD'S METAL
400
200
100
60
40
20
10
6
4
2
1
0.6
0.4
0.2
.1
.08
.06
.02
.01
.006
.004
ENTHALPY , joules / gm (multiply value by 10^{-3})
100
60
40
20
10
6
4
2
1
0.6
0.4
0.2
0.1
.06
.04
.02
.01
.006
.004
.002
ENTHALPY , BTU / lb (multiply value by 10^{-3})
1
2
3
4
5
6
8
10
20
TEMPERATURE , °K

SPECIFIC HEAT, ENTHALPY of ARALDITE

(TYPE I)

Source of Data:

Parkinson, D. H. and Quarrington, J. E., Brit. J. Appl. Phys. 5, 219-20 (1954)

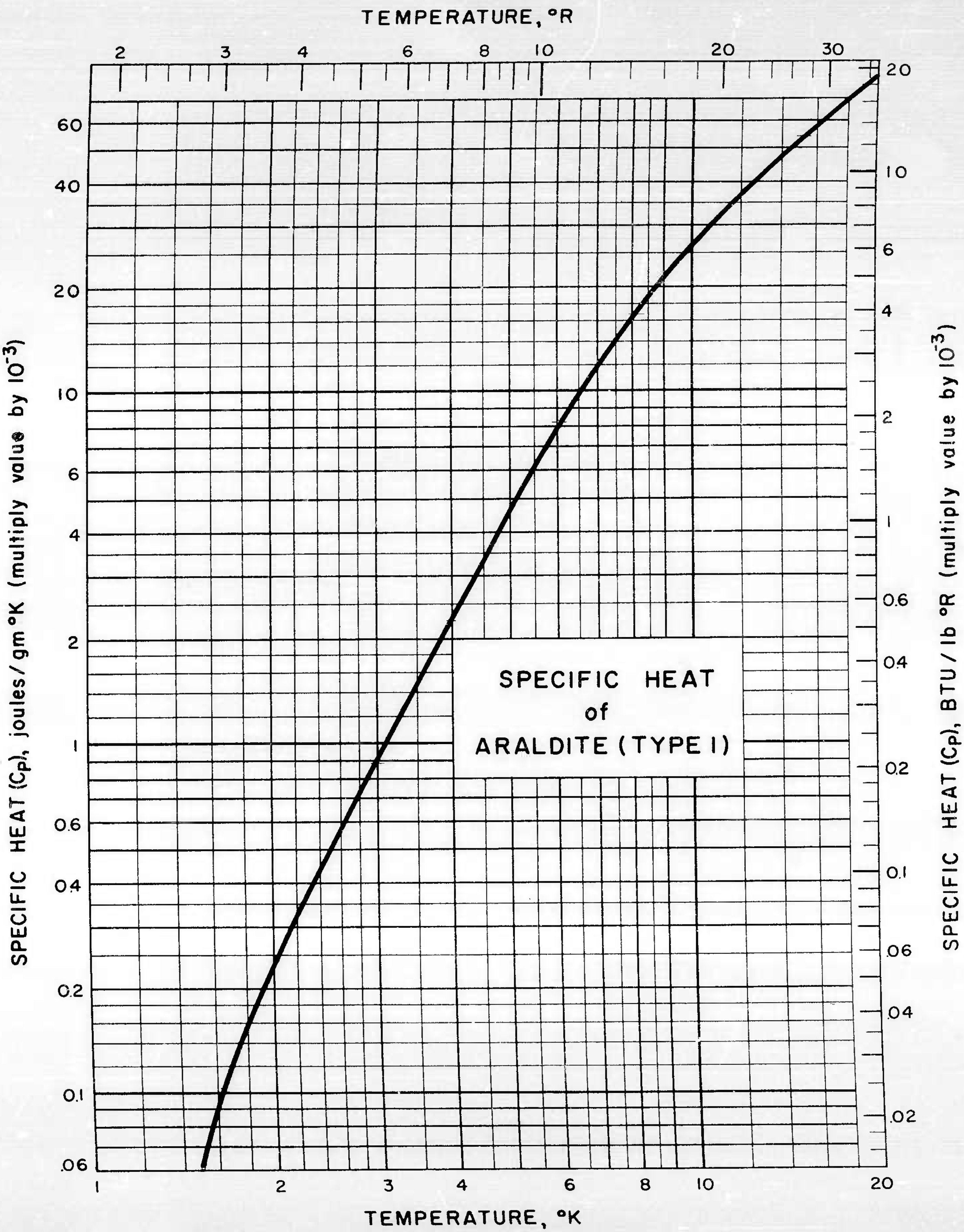
Comments:

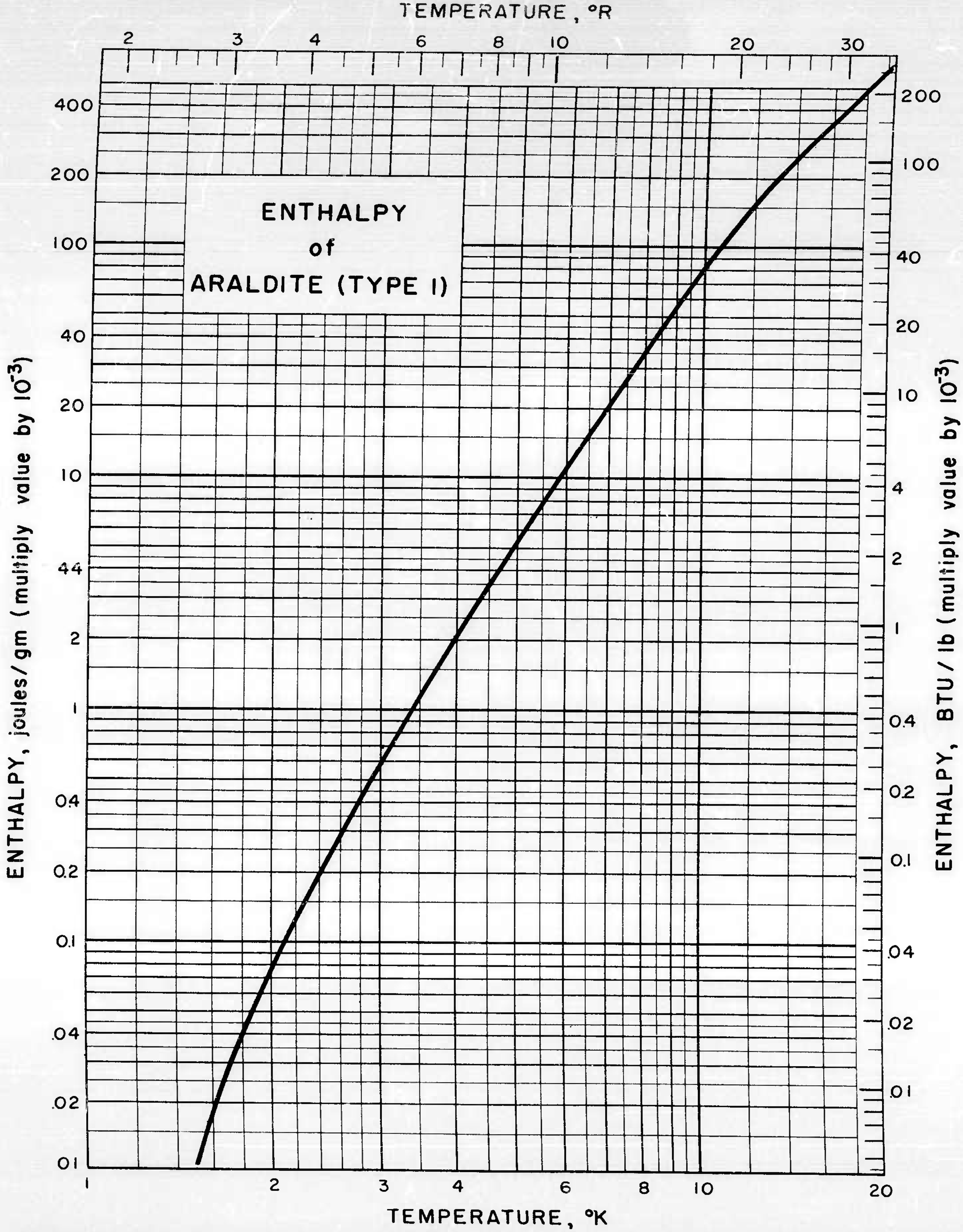
Sample prepared according to manufacturer's directions.

Table of Selected Values

Temp. °K	C_p j/gm-°K	H j/gm
1.5	0.000 06	0.000 01
2	.000 24	.000 08
3	.000 89	.000 60
4	.002 25	.002 10
6	.008 2	.011 7
8	.016 9	.036 7
10	.027 2	.080 7
15	.054 2	.284
20	.081 1	.623

RJC/JJG Issued: 12-18-59


TEMPERATURE, °R
2
3
4
6
8
10
20
30
SPECIFIC HEAT (Cp), joules/gm °K (multiply value by 10^-3)
60
40
20
10
6
4
2
1
0.6
0.4
0.2
0.1
.06
SPECIFIC HEAT (Cp), BTU/lb °R (multiply value by 10^-3)
20
10
6
4
2
1
0.6
0.4
0.2
0.1
.06
.04
.02
SPECIFIC HEAT
of
ARALDITE (TYPE I)
1
2
3
4
6
8
10
20
TEMPERATURE, °K



TEMPERATURE, °R
2
3
4
6
8
10
20
30
ENTHALPY
of
ARALDITE (TYPE I)
ENTHALPY, joules/gm (multiply value by 10^{-3})
400
200
100
40
20
10
44
2
1
0.4
0.2
0.1
.04
.02
01
ENTHALPY, BTU/lb (multiply value by 10^{-3})
200
100
40
20
10
4
2
1
0.4
0.2
0.1
.04
.02
.01
1
2
3
4
6
8
10
20
TEMPERATURE, °K

SPECIFIC HEAT, ENTHALPY of PYREX

Source of Data:

Smith, P. L. and Wolcott, N. M., Phil. Mag. 1, 854-65 (1956)

Comments:

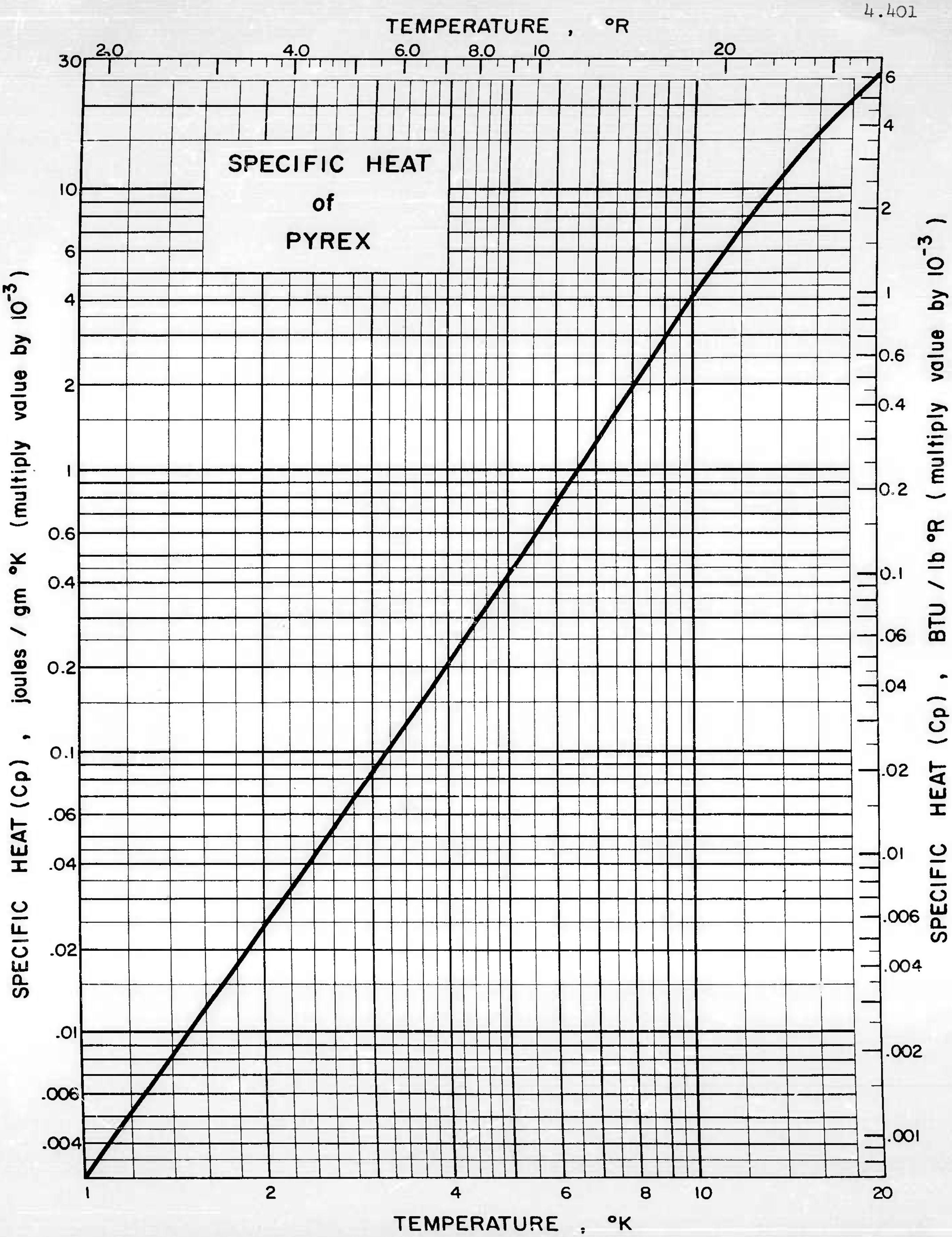
The values for C_p at temperatures less than 5°K can be expressed by the formula:

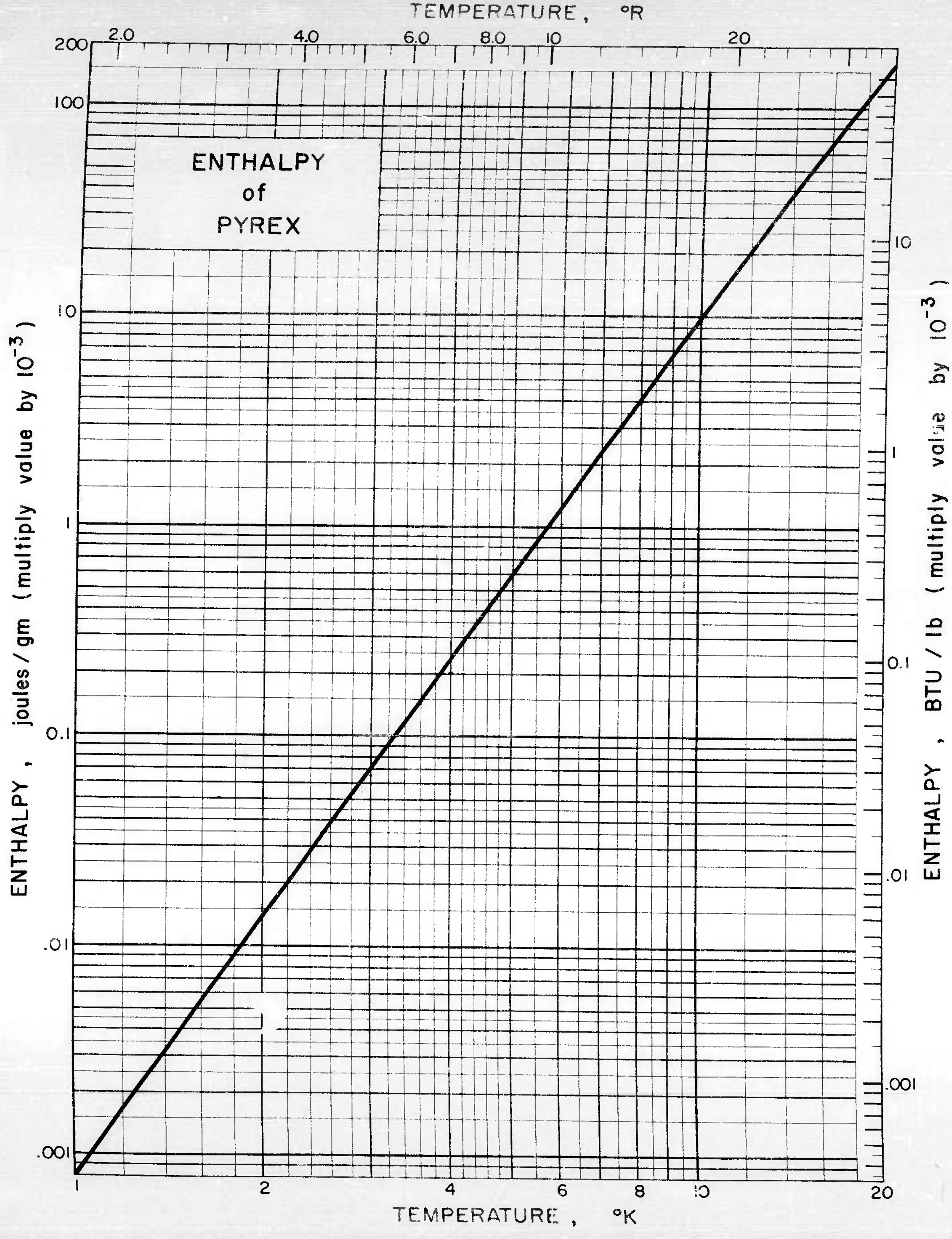
$$C_p = (3.14 \times 10^{-6})T^3 \text{ j/gm-°K}$$

Table of Selected Values

Temp. °K	C_p j/gm-°K	H j/gm
1	0.000 0031	0.000 0008
2	.000 025	.000 013
3	.000 084	.000 064
4	.000 201	.000 201
6	.000 753	.001 04
8	.002 09	.003 94
10	.004 19	.010 0
15	.013 7	.052 5
20	.027 4	.154

RJC/JJG/VDA Issued: 12-14-59


TEMPERATURE , °R
2.0
4.0
6.0
8.0
10
20
SPECIFIC HEAT
of
PYREX
30
10
6
4
2
1
0.6
0.4
0.2
0.1
.06
.04
.02
.01
.006
.004
6
4
2
1
0.6
0.4
0.2
0.1
.06
.04
.02
.01
.006
.004
.002
.001
SPECIFIC HEAT (Cp) , joules / gm °K (multiply value by 10^{-3})
SPECIFIC HEAT (Cp) , BTU / lb °R (multiply value by 10^{-3})
1
2
4
6
8
10
20
TEMPERATURE , °K


TEMPERATURE, °R
2.0
4.0
6.0
8.0
10
20
ENTHALPY
of
PYREX
ENTHALPY, joules / gm (multiply value by 10^{-3})
200
100
10
1
0.1
.01
.001
ENTHALPY, BTU / lb (multiply value by 10^{-3})
10
1
0.1
.01
.001
1
2
4
6
8
10
20
TEMPERATURE, °K

SPECIFIC HEAT and ENTHALPY of QUARTZ

Sources of Data:

Anderson, C. T., J. Am. Chem. Soc. 58, 568 (1936)

Westrum, E. F.; data reproduced in Lord, R.C. and Morrow, J. C., J. Chem. Phys. 26, 230 (1957)

Other References:

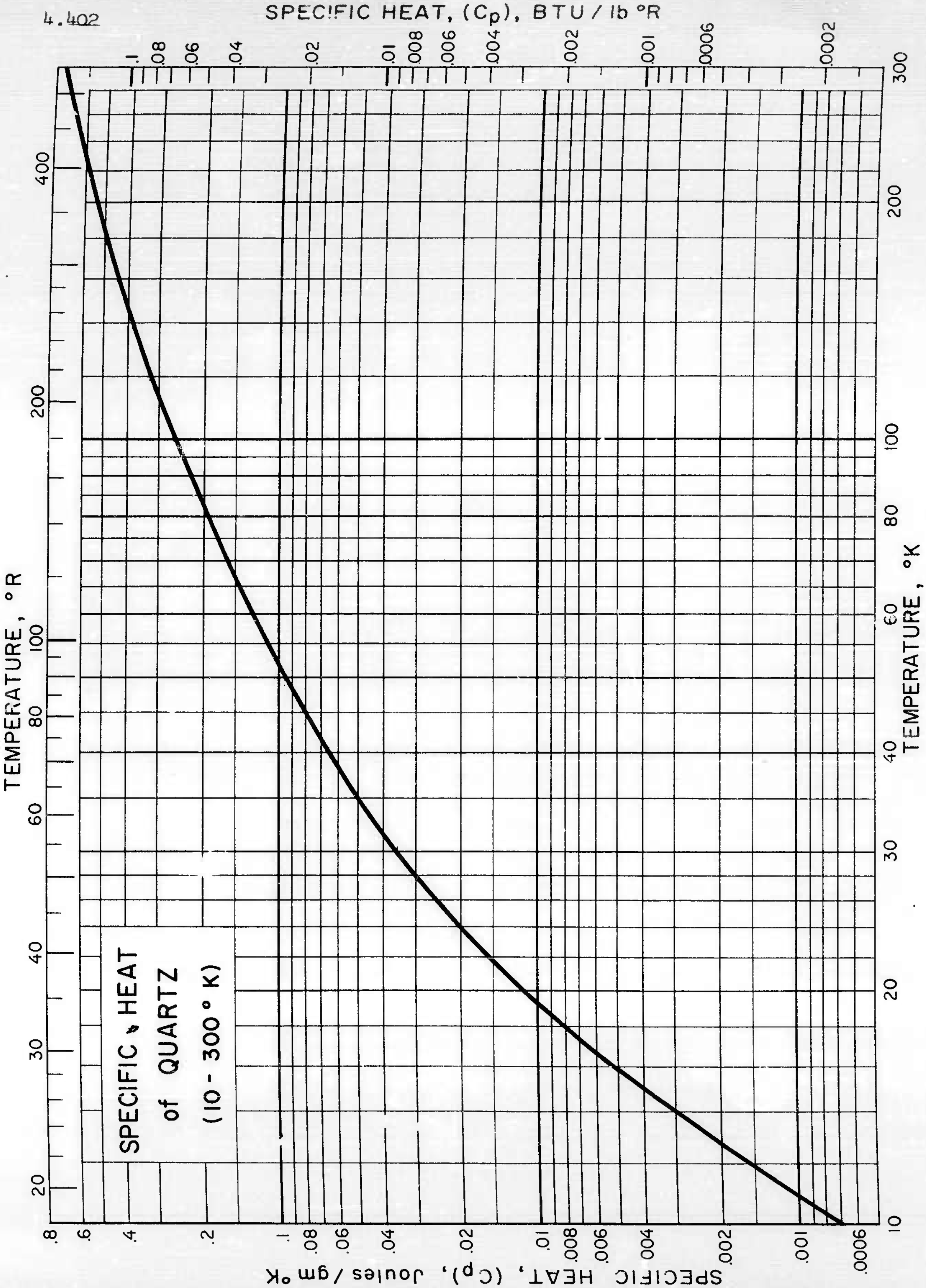
Gunther, P., Z. anorg. u allgem. Chem. 116, 71 (1921)

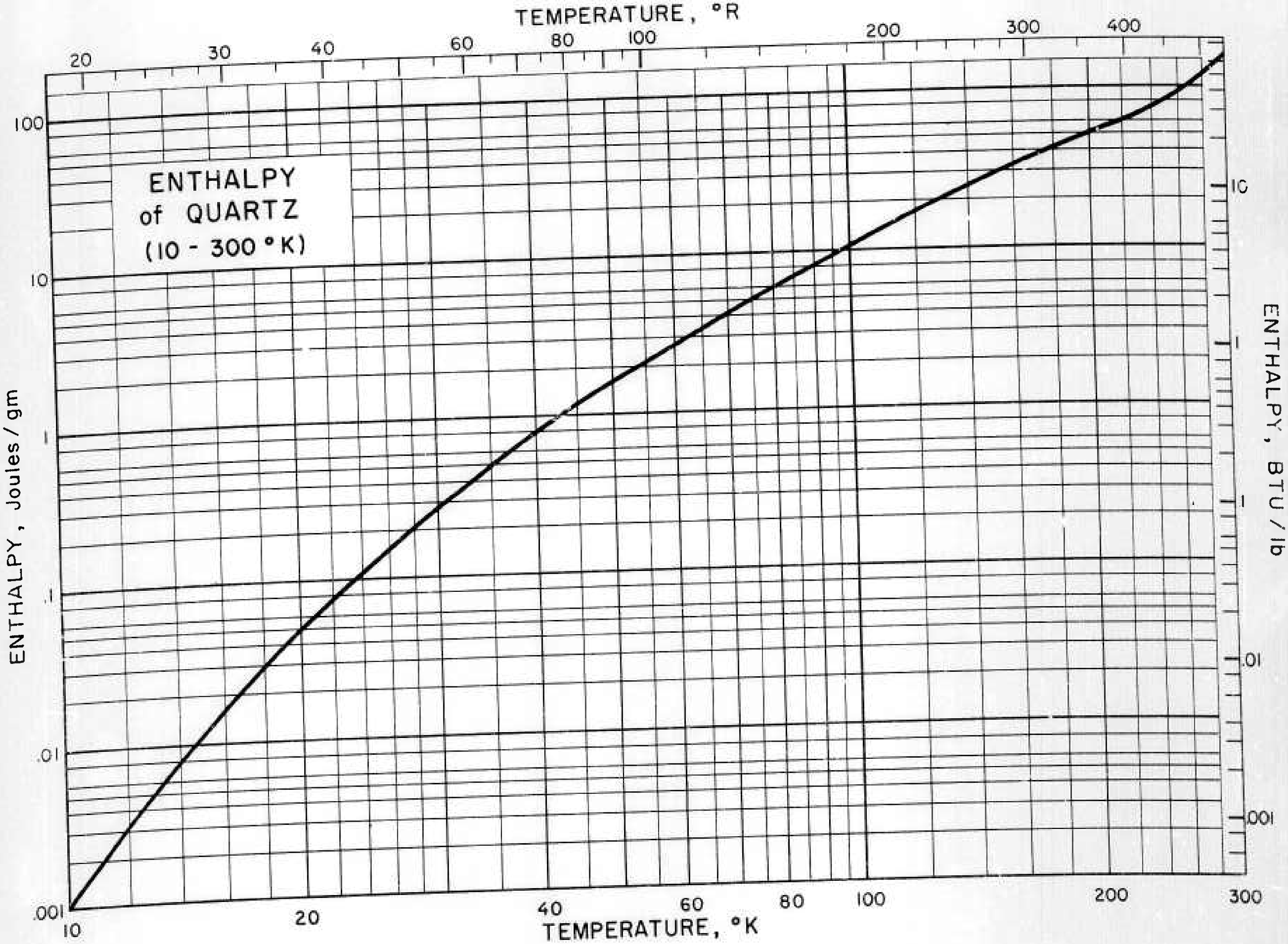
Nernst, W., Ann. Physik (4) 36, 395 (1911)

Table of Selected Values

T °K	Cp j/gm-°K	H j/gm	T °K	Cp j/gm-°K	H j/gm
10	0.0007	0.001	100	0.261	10.51
15	.0040	0.012	120	.325	16.37
20	.0113	0.049	140	.385	23.48
25	.0221	0.131	160	.441	31.75
30	.0353	0.273	180	.494	41.1
40	.0653	0.773	200	.543	51.5
50	.0969	1.583	220	.588	62.8
60	.129	2.71	240	.631	75.0
70	.162	4.17	260	.671	88.0
80	.195	5.95	280	.709	101.8
90	.228	8.07	300	.745	116.4

RJC Issued: 6-5-59


SPECIFIC HEAT, (Cp), BTU / lb °R
.1 .08 .06 .04 .02 .01 .008 .006 .004 .002 .001 .0006 .0002
TEMPERATURE, °R
20 30 40 60 80 100 200 400
TEMPERATURE, °K
10 20 30 40 60 80 100 200 300
SPECIFIC HEAT, (Cp), Joules / gm °K
.8 .6 .4 .2 .1 .08 .06 .04 .02 .01 .008 .006 .004 .002 .001 .0006
SPECIFIC HEAT
of QUARTZ
(10 - 300° K)


ENTHALPY
of QUARTZ
(10 - 300 °K)
TEMPERATURE, °R
20
30
40
60
80
100
200
300
400
TEMPERATURE, °K
10
20
40
60
80
100
200
300
ENTHALPY, Joules / gm
.001
.01
.1
1
10
100
ENTHALPY, BTU / lb
.001
.01
.1
1
10

SPECIFIC HEAT, ENTHALPY of ICE

Sources of Data:

Giauque, W. F. and Stout, J. W., J. Am. Chem. Soc. 58, 1144 (1936)

Simon, F., unpublished (1923). Data reproduced in Giauque and Stout (see above).

Other References:

Barnes, W. H. and Maas, O., Can. J. Research 3, 205 (1930)

Duyckaerts, G., Mem. soc. roy. sci. Liege 6, 325 (1945)

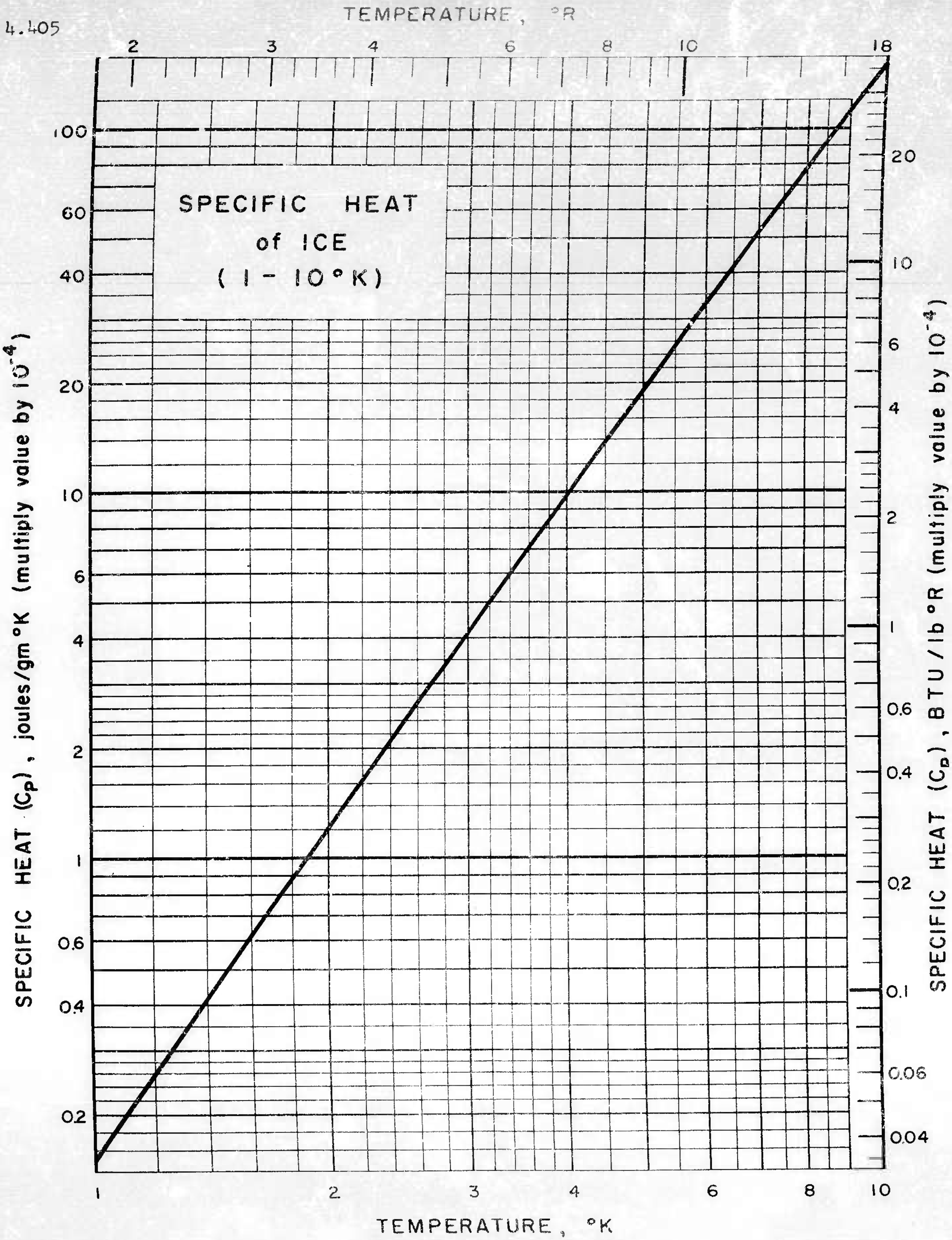
Nernst, W., Ann. physik, ser. 4, 36, 395 (1911)

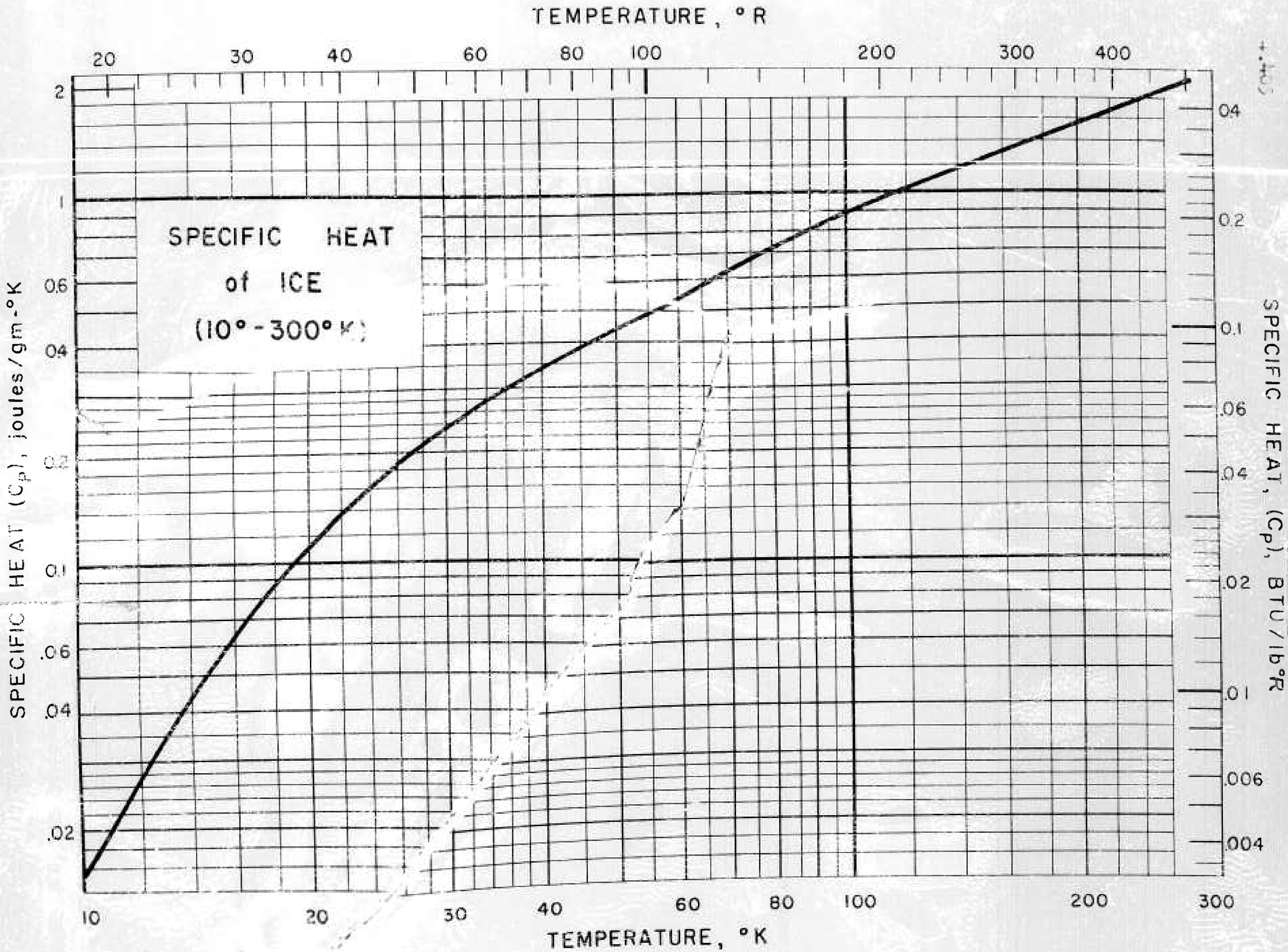
Pollitzer, F., Z. Elektrochem. 19, 513 (1913)

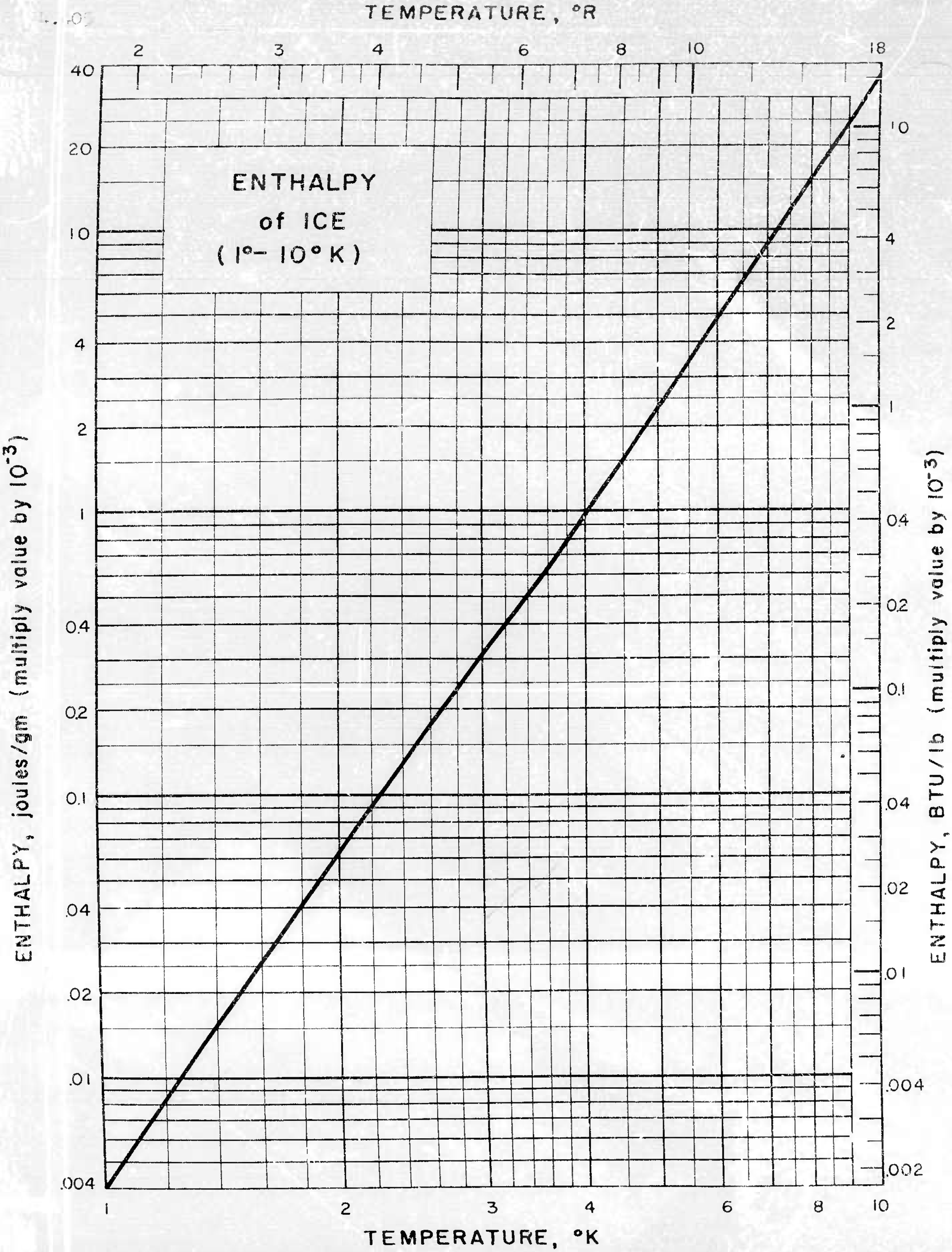
Table of Selected Values

Temp. °K	C_p j/gm-°K	H j/gm	Temp. °K	C_p j/gm-°K	H j/gm
1	0.000 015	0.000 004	60	0.535	13.97
2	0.000 12	0.000 061	70	0.627	19.78
3	0.000 41	0.000 31	80	0.716	26.49
4	0.000 98	0.000 98	90	0.801	34.06
6	0.003 3	0.004 9	100	0.882	42.47
8	0.007 8	0.015 6	120	1.03	61.6
10	0.015 2	0.038	140	1.16	83.5
12	0.026 5	0.079	160	1.29	108.0
14	0.043	0.148	180	1.43	135.2
16	0.065	0.255	200	1.57	165.1
18	0.090	0.410	220	1.72	197.9
20	0.114	0.615	240	1.86	233.7
30	0.229	2.33	260	2.01	272.4
40	0.340	5.18	270	2.08	292.8
50	0.440	9.09	273.15	2.10	299.4

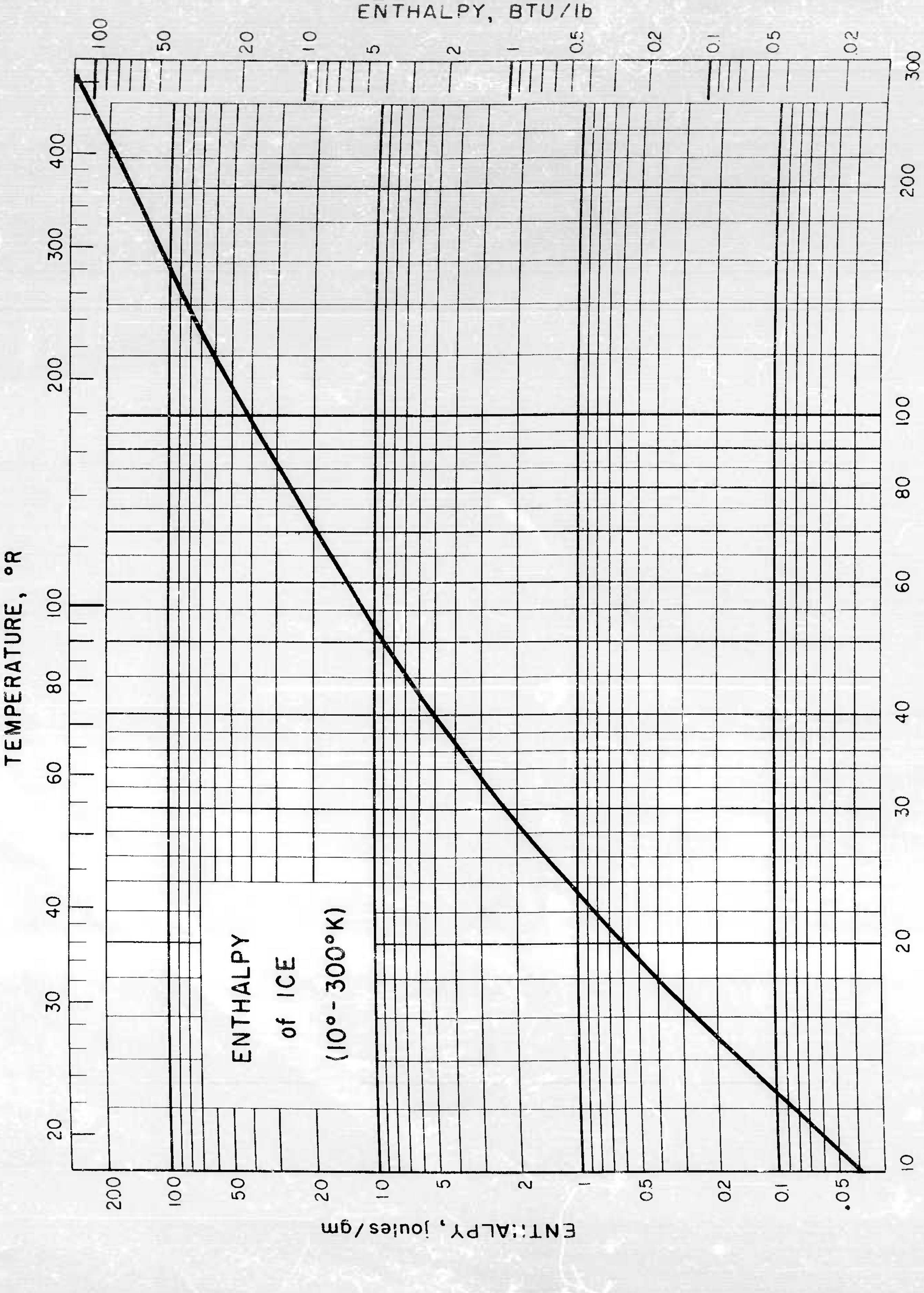
RJC Issued: 12-18-59


TEMPERATURE, °R
2
3
4
6
8
10
18
SPECIFIC HEAT
of ICE
(1 - 10°K)
100
60
40
20
10
6
4
2
1
0.6
0.4
0.2
SPECIFIC HEAT (C_p), joules/gm°K (multiply value by 10^{-4})
20
10
6
4
2
1
0.6
0.4
0.2
0.1
0.06
0.04
SPECIFIC HEAT (C_p), BTU/lb°R (multiply value by 10^{-4})
1
2
3
4
6
8
10
TEMPERATURE, °K


SPECIFIC HEAT
of ICE
(10°-300°K)
TEMPERATURE, °R
20
30
40
60
80
100
200
300
400
TEMPERATURE, °K
10
20
30
40
60
80
100
200
300
SPECIFIC HEAT (Cp), joules/gm-°K
2
1
0.6
0.4
0.2
0.1
.06
.04
.02
SPECIFIC HEAT, (Cp), BTU/lb°R
.04
0.2
0.1
.06
.04
.02
.01
.006
.004



TEMPERATURE, °R
2
3
4
6
8
10
18
ENTHALPY
of ICE
(1°- 10° K)
40
20
10
4
2
1
0.4
0.2
0.1
.04
.02
.01
.004
10
4
2
1
0.4
0.2
0.1
.04
.02
.01
.004
.002
ENTHALPY, joules/gm (multiply value by 10^{-3})
ENTHALPY, BTU/lb (multiply value by 10^{-3})
1
2
3
4
6
8
10
TEMPERATURE, °K


ENTHALPY, BTU/lb
100
50
20
10
5
2
1
0.5
0.2
0.1
.05
.02
TEMPERATURE, °R
400
300
200
100
80
60
40
30
20
TEMPERATURE, °K
300
200
100
80
60
40
30
20
10
ENTHALPY
of ICE
(10° - 300°K)
200
100
50
20
10
5
2
1
0.5
0.2
0.1
.05
ENTHALPY, joules/gm

SPECIFIC HEAT, ENTHALPY of MgO

Source of Data:

Giauque, W. R. and Archibald, R. C., J. Am. Chem. Soc. 59, 561 (1937)

Other References:

Gunther, P., Ann. phys. 51, 838 (1916)

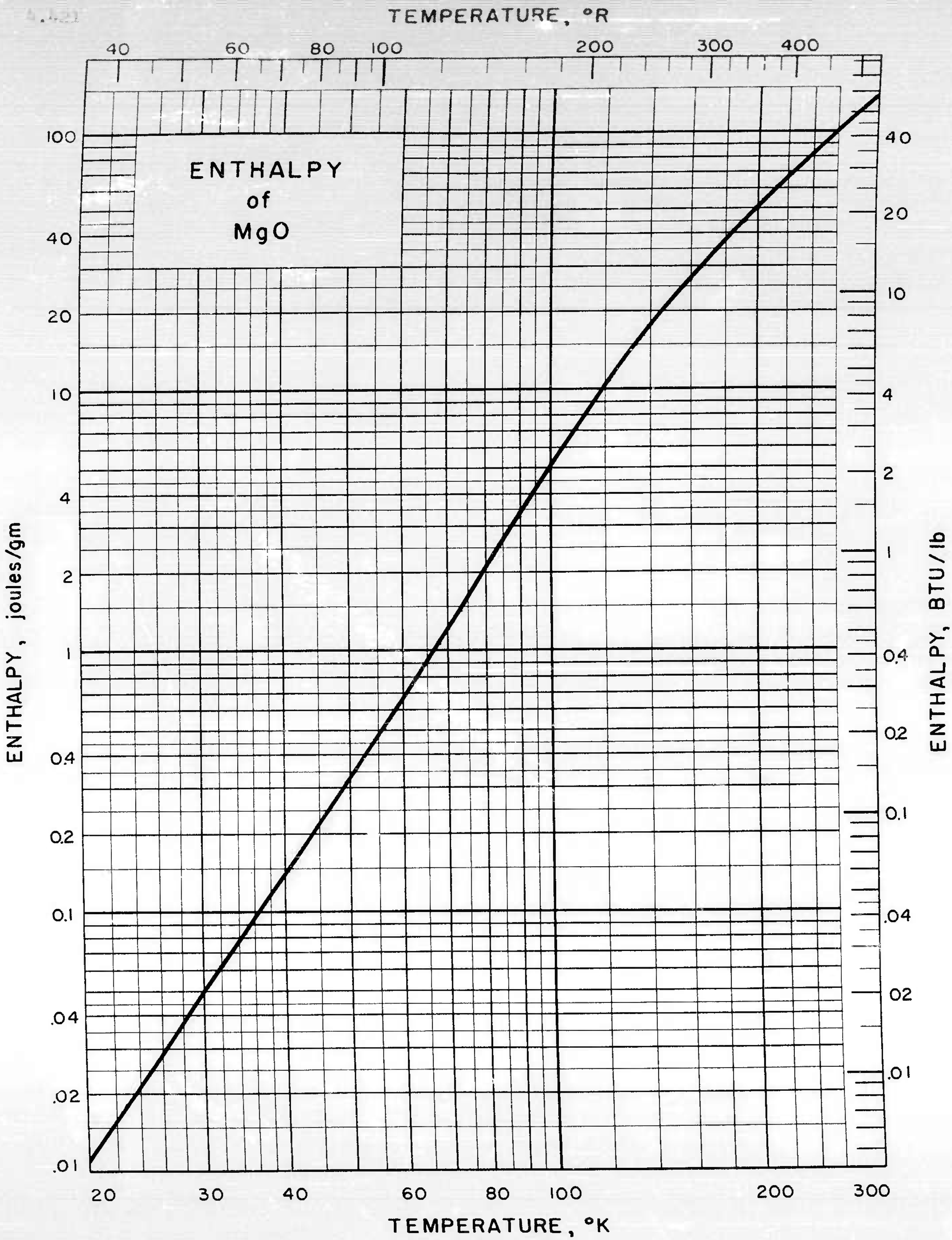
Parks, G. S. and Kelley, K. K., J. Phys. Chem. 30, 47 (1926)

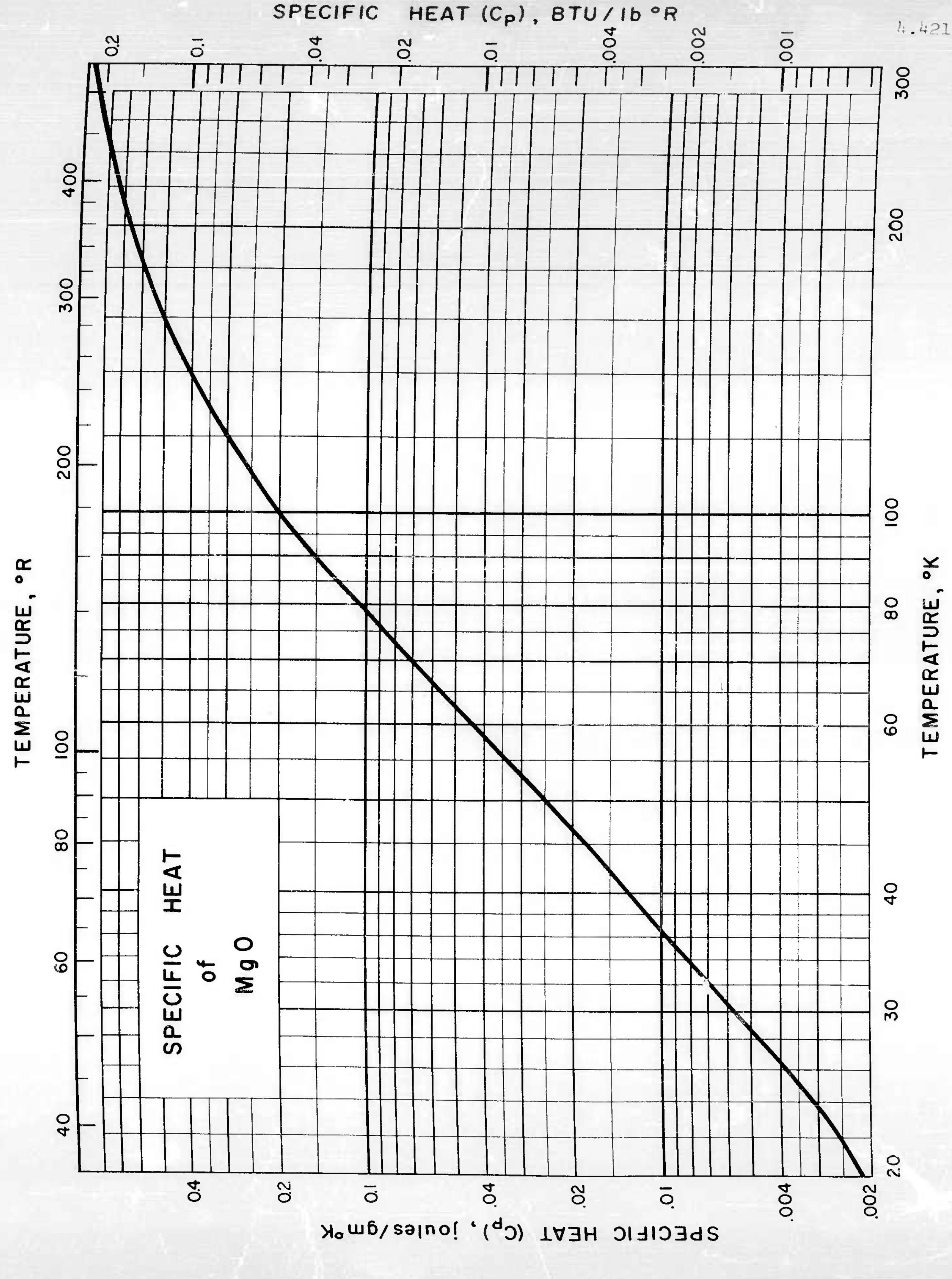
Comments:

The data of Parks and Kelley are believed to be the most representative of bulk crystalline MgO but unfortunately do not extend below 94°K. Accordingly we have used the more complete data of Giauque and Archibald, even though they were obtained using a fine powder sample and appear to be too high on that account. The extra specific heat due to the surface can be estimated by comparison with the data of Parks and Kelley and also by fitting the data below 70°K (approx. $\Theta_0/12$) with the expression $C = aT^2 + bT^3$, in which the first term gives the surface contribution [Keesom and Pearlman, Handbuch der Physik XIV, 332-3 (1956)]. If this interpretation is correct one finds that the surface term amounts to about one-third of the total specific heat at 20°, about 5% at 100°, and is negligible at 300°K.

Temp. °K	C_p j/gm-°K	H j/gm	Temp. °K	C_p j/gm-°K	H j/gm
20	0.0022	0.011	100	0.208	5.31
25	.0036	.025	120	.312	10.5
30	.0059	.048	140	.42	17.8
35	.0090	.084	160	.51	27.0
40	.0131	.139	180	.60	38.1
45	.0182	.217	200	.68	50.9
50	.0243	.322	220	.74	65.1
60	.041	.64	240	.80	80.6
70	.073	1.20	260	.85	97.2
80	.113	2.13	280	.90	114.7
90	.159	3.48	300	.94	133.1

RJC/JJG Issued: 10-21-59
Revised: 5/20/60


ENTHALPY
of
MgO
TEMPERATURE, °R
40
60
80
100
200
300
400
ENTHALPY, joules/gm
100
40
20
10
4
2
1
0.4
0.2
0.1
.04
.02
.01
ENTHALPY, BTU/lb
40
20
10
4
2
1
0.4
0.2
0.1
.04
.02
.01
20
30
40
60
80
100
200
300
TEMPERATURE, °K


SPECIFIC HEAT (Cp), BTU/lb °R
0.2
0.1
.04
.02
.01
.004
.002
.001
TEMPERATURE, °R
400
300
200
100
80
60
40
TEMPERATURE, °K
300
200
100
80
60
40
30
20
SPECIFIC HEAT of MgO
SPECIFIC HEAT (Cp), joules/gm°K
0.4
0.2
0.1
.04
.02
.01
.004
.002

SPECIFIC HEAT AND ENTHALPY OF GR-S (BUNA S) RUBBER (1-3 BUTADIENE, 25 WT. % STYRENE)

Source of Data:

Rands, R. D. Jr., Ferguson, W. T. and Prather, J. L., J. Research Natl. Bur. Standards 33, 63-70 (1944)

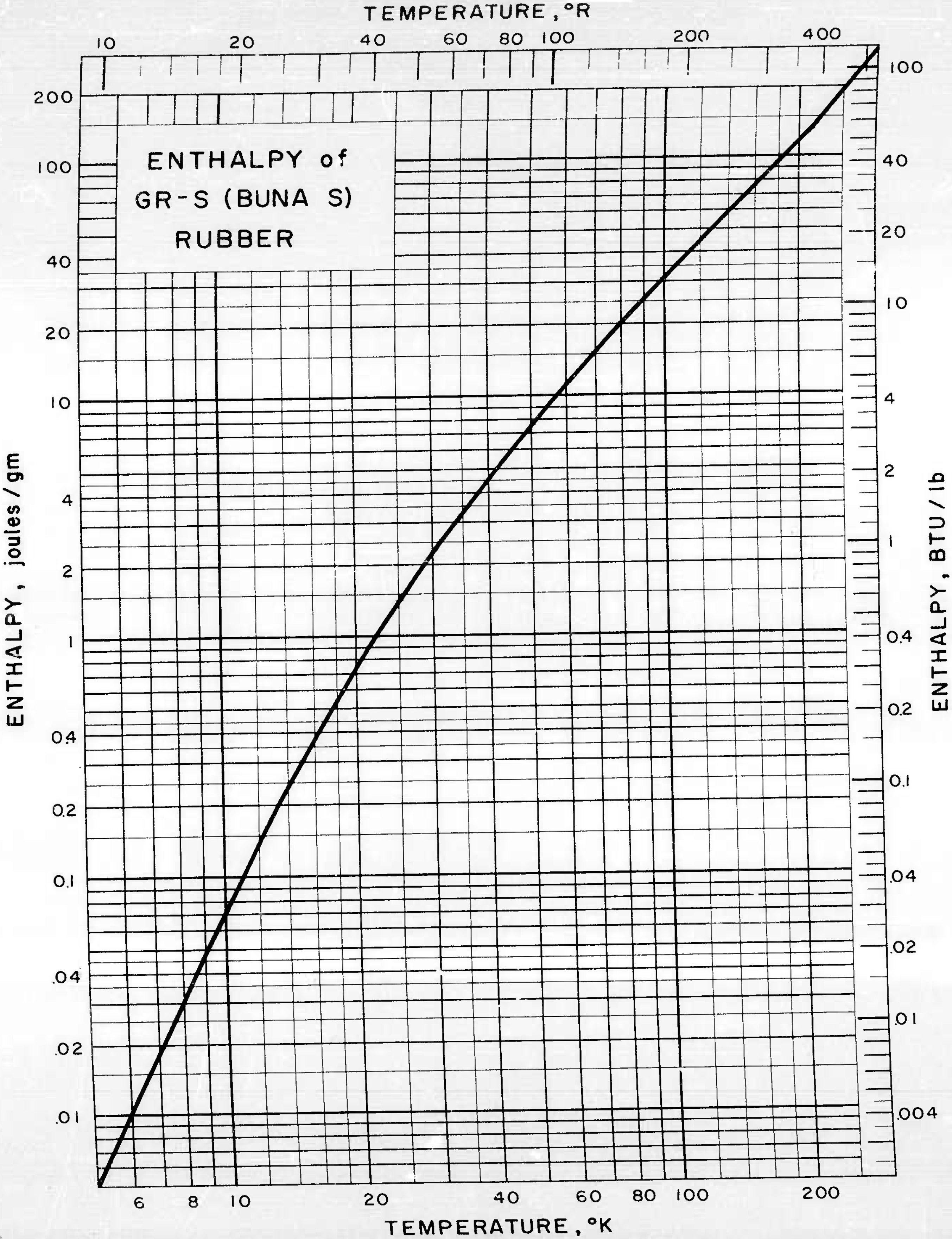
Comments:

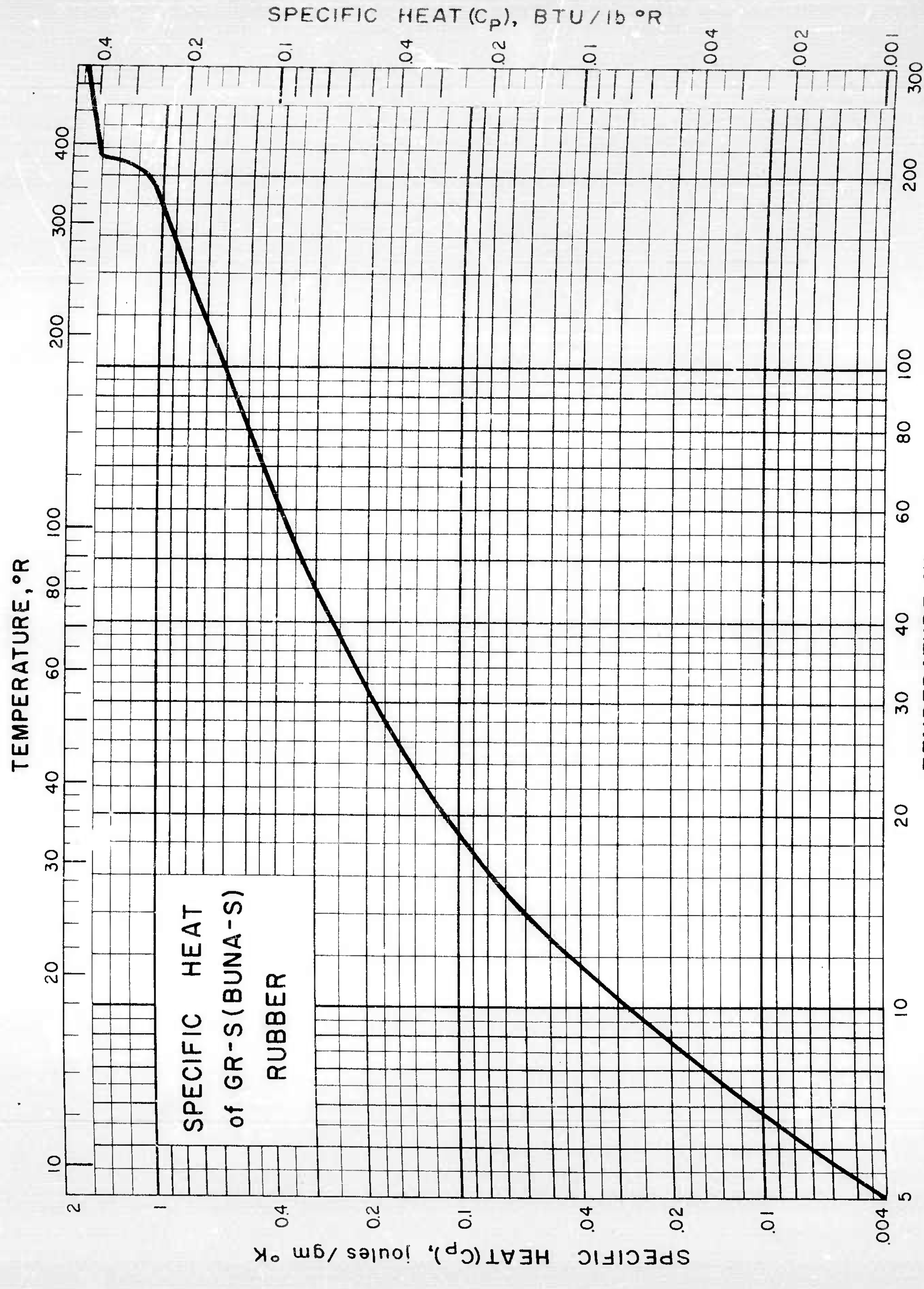
A second-order transition which indicates a change of slope occurs at about 212 °K. Hysteresis occurs in the region immediately below this transition.

Table of Selected Values

Temp. °K	C_p j/gm-°K	H j/gm	Temp. °K	C_p j/gm-°K	H j/gm
5	0.004	0.005	120	0.711	45.0
10	.028	.07	140	.811	60.2
15	.070	.31	160	.911	77.4
20	.113	.77	180	1.01	96.7
25	.155	1.44	200	1.12	118.0
30	.196	2.32	210	1.34	130.0
40	.272	4.66	212	1.66	133.3
50	.338	7.72	220	1.68	146.1
60	.399	11.40	240	1.73	180.1
70	.455	15.68	260	1.78	215.2
80	.509	20.50	280	1.84	251.4
90	.562	25.86	300	1.90	288.7
100	.612	31.74			

R. /JJG Issued: 10-21-59


TEMPERATURE, °R
10
20
40
60
80
100
200
400
ENTHALPY of
GR-S (BUNA S)
RUBBER
200
100
40
20
10
4
2
1
0.4
0.2
0.1
.04
.02
.01
ENTHALPY, joules / gm
100
40
20
10
4
2
1
0.4
0.2
0.1
.04
.02
.01
.004
ENTHALPY, BTU / lb
6
8
10
20
40
60
80
100
200
TEMPERATURE, °K


SPECIFIC HEAT (Cp), BTU/lb °R
.4
.2
.1
.04
.02
.01
.004
.002
.001
TEMPERATURE, °R
400
300
200
100
80
60
40
30
20
10
TEMPERATURE, °K
300
200
100
80
60
40
30
20
10
5
SPECIFIC HEAT of GR-S(BUNA-S) RUBBER
SPECIFIC HEAT(Cp), joules/gm °K
2
1
0.4
0.2
0.1
.04
.02
.01
.004

SPECIFIC HEAT and ENTHALPY of NATURAL RUBBER HYDROCARBON (Amorphous)

Source of Data:

Bekkedahl, N., and Matheson, H. J., Research Nat. Bur. Standards 15, 503 (1934)

Comments:

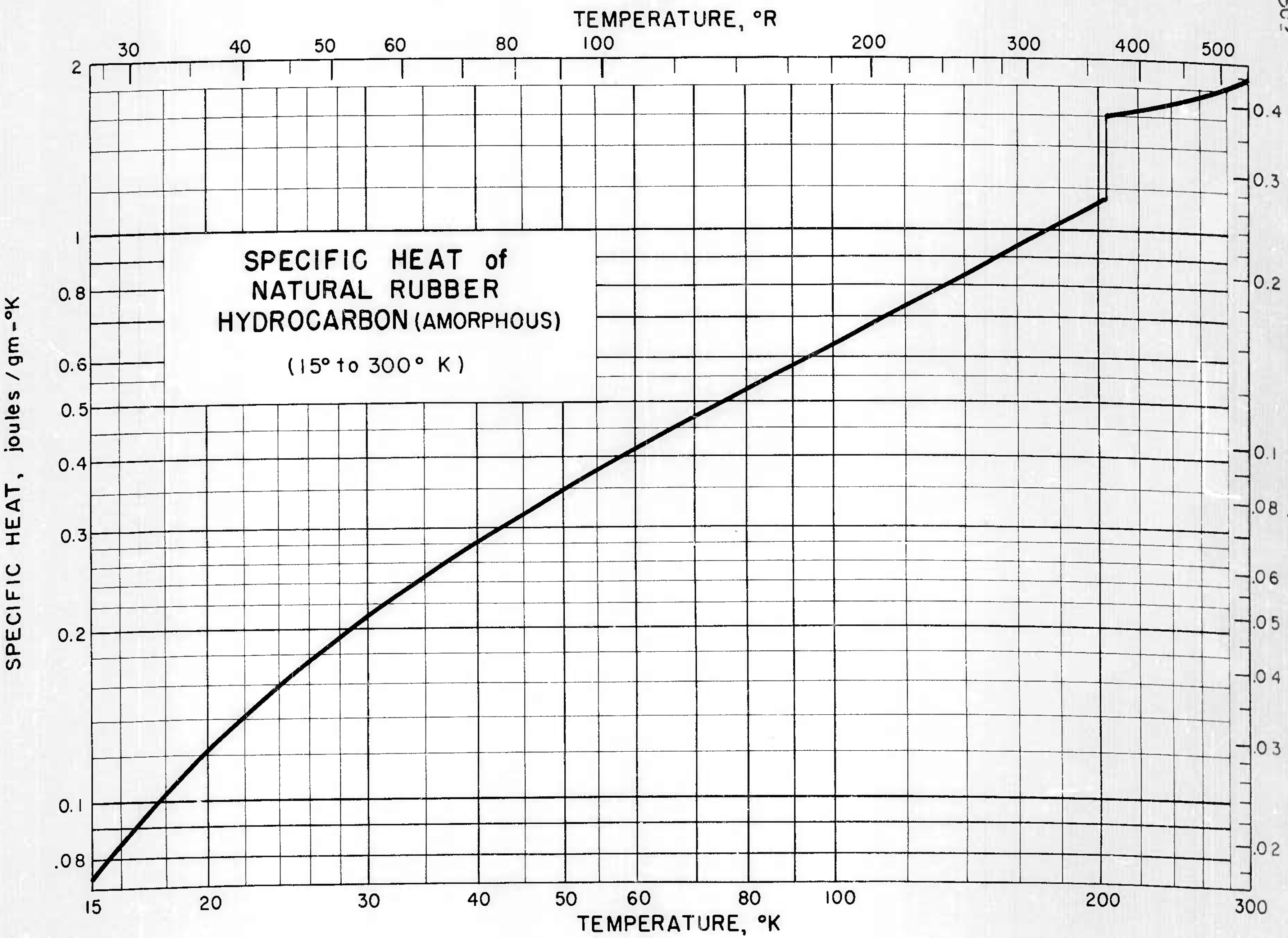
These data apply to pure hydrocarbon polymer extracted from latex. Commerical natural rubber differs from this by containing various additives and having been vulcanized. No low-temperature data for vulcanized rubber have been found, and the data on this sheet are presented as being the closest available approximation thereto. A second-order transformation (glass transformation) occurs at about 200°K. The data in this region are the least applicable to other forms of rubber since the temperature and shape of the transition in C_p will be rather strongly affected by vulcanization and additives.

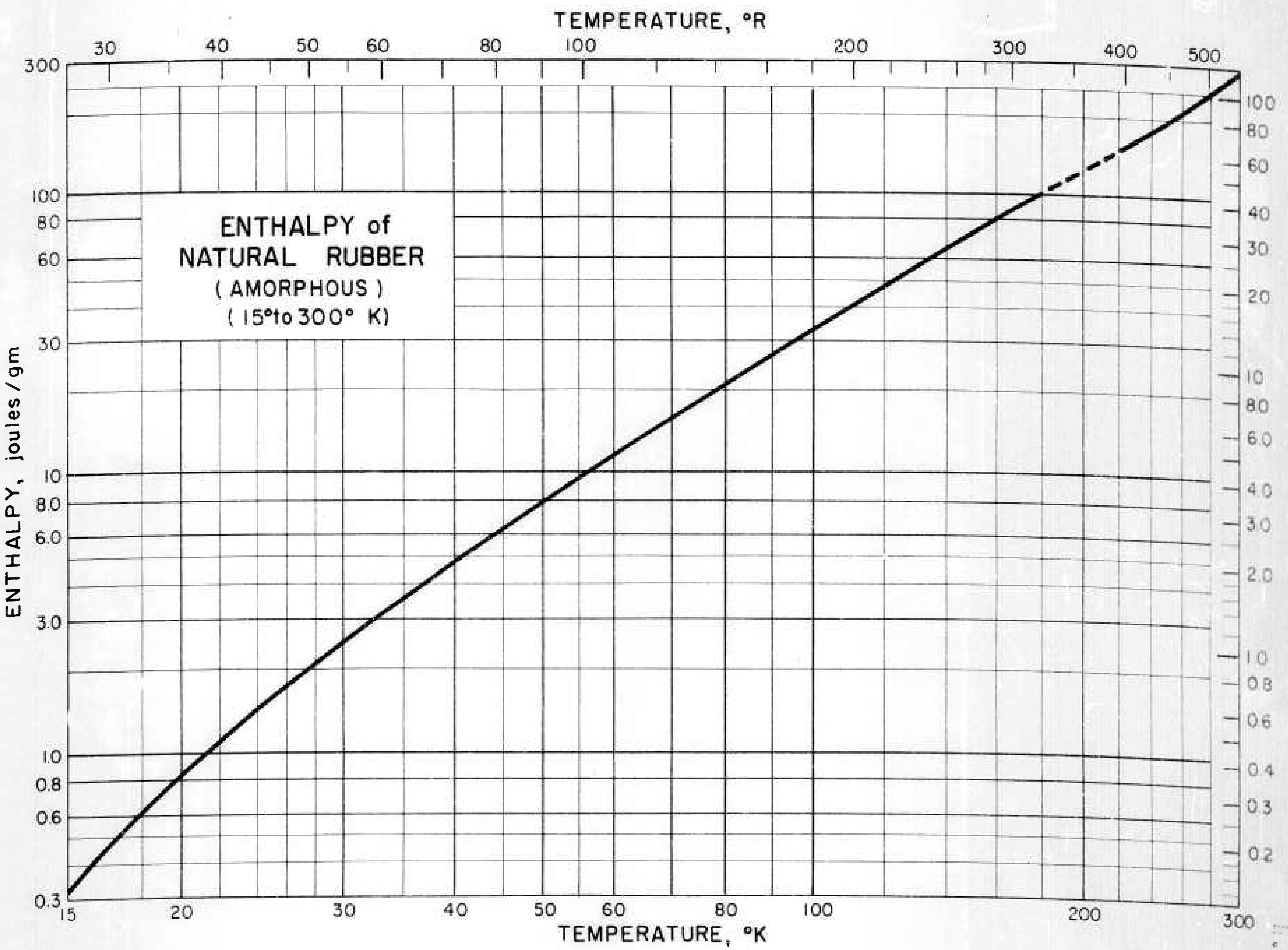
Table of Selected Values

T °K	Cp j/gm-°K	H j/gm
15	0.073	0.32
20	.117	0.80
30	.204	2.41
40	.282	4.84
50	.352	8.01
60	.418	11.87
70	.480	16.36
80	.537	21.45
90	.596	27.12
100	.646	33.34
120	.75	47.3
140	.84	63.2
160	.94	81.0
180	1.03	100.7
190	1.08	
195	1.10	
200*	1.44	
205	1.60	
210	1.61	
220	1.64	155.0
240	1.70	188.4
260	1.75	222.9
280	1.81	258.4
290	1.84	276.6
300	1.89	295.3

* Second-order transition

RJC Issued: 12-14-59


TEMPERATURE, °R
30
40
50
60
80
100
200
300
400
500
SPECIFIC HEAT of
NATURAL RUBBER
HYDROCARBON (AMORPHOUS)
(15° to 300° K)
SPECIFIC HEAT, joules / gm-°K
2
1
0.8
0.6
0.5
0.4
0.3
0.2
0.1
.08
SPECIFIC HEAT, BTU / lb °R
0.4
0.3
0.2
0.1
.08
.06
.05
.04
.03
.02
15
20
30
40
50
60
80
100
200
300
TEMPERATURE, °K



TEMPERATURE, °R
ENTHALPY of
NATURAL RUBBER
(AMORPHOUS)
(15° to 300° K)
ENTHALPY, joules / gm
TEMPERATURE, °K
ENTHALPY, BTU/lb

4.502

SPECIFIC HEAT and ENTHALPY of TEFLON (MOLDED)

Source of Data:

Furukawa, G. T., McCoskey, R. E. and King, G. J., J. Research Natl. Bur. Standards 49, 273 (1952)

Other References:

Noer, R. J., Dempsey, C. W. and Gordon, J. E., Bull. Am. Phys. Soc. 4, 108 (1959)

Comments:

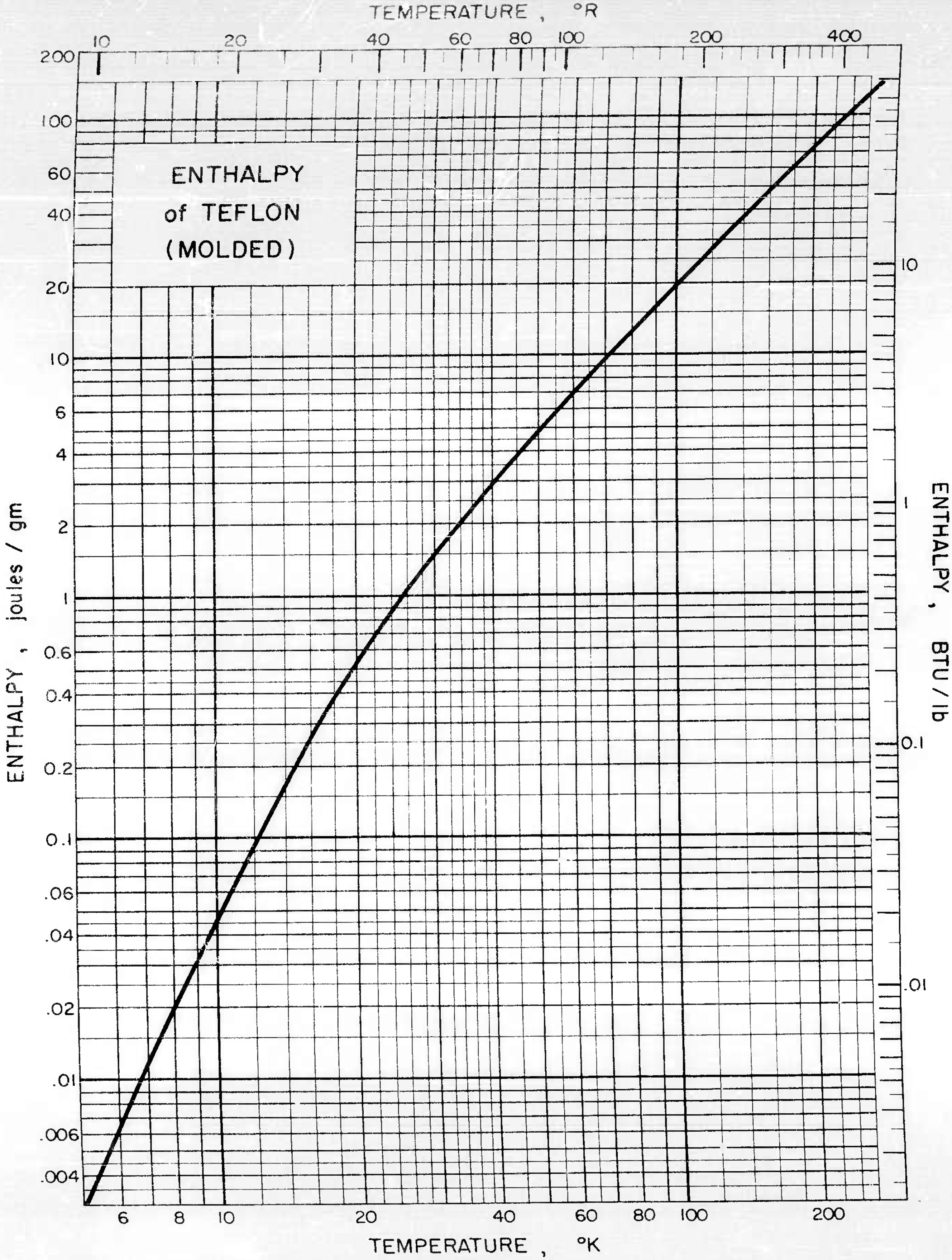
The above reference (Furukawa, et al.), also gives data on molded and annealed, molded and quenched, and powdered teflon. The effects of heat treatment do not exceed 3% and are not significant below 150°K. The data indicate a second-order transition at about 160°K and two first-order transitions between 280°K and 310°K. Thermal hysteresis occurs in these regions. Because of this effect, data are not presented for the region 280°K to 310°K. Specific heat values at 5°K and 10°K were obtained through computation involving the Debye temperature, Θ_0 values extrapolated from the 15-30°K range.

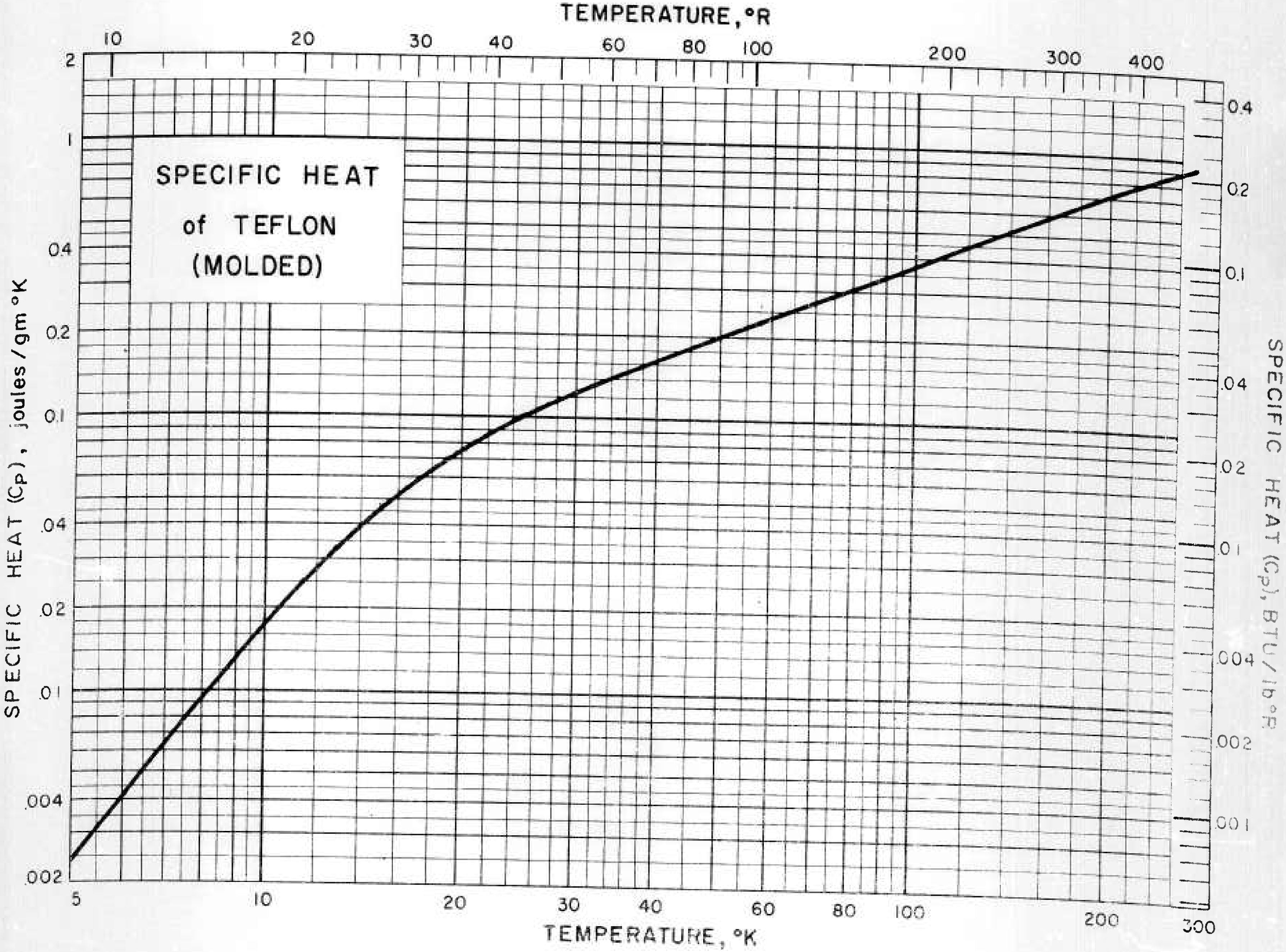
Noer, et al. report an approximate formula for the specific heat of teflon between 1.4°K and 4.2°K which is not in good agreement with the extrapolated value of Furukawa, et al. tabulated below. Their approximate formula is given as

$$C \cong 4 \times 10^{-5} T^3 \text{ j/gm-°K}$$

Temp. °K	C_p j/gm °K	H j/gm	Temp. °K	C_p j/gm °K	H j/gm
5	0.0024	0.003	100	0.386	19.51
10	.018	0.047	120	0.457	27.9
15	.048	0.21	140	0.525	37.7
20	.076	0.52	160	0.598	49.0
25	.102	0.97	180	0.677	61.7
30	.125	1.54	200	0.741	75.9
40	.165	2.99	220	0.798	91.3
50	.202	4.83	240	0.853	107.8
60	.238	7.02	260	0.193	125.5
70	.274	9.59	280	1.01	144.6
80	.312	12.52	310	1.02	179.3
90	.350	15.83			

RJC/JJG/VDA Issued: 12-14-59
Revised: 5-20-60


4.503
TEMPERATURE , °R
10
20
40
60
80
100
200
400
ENTHALPY
of TEFLON
(MOLDED)
200
100
60
40
20
10
6
4
2
1
0.6
0.4
0.2
0.1
.06
.04
.02
.01
.006
.004
ENTHALPY , joules / gm
10
1
0.1
.01
ENTHALPY , BTU / lb
6
8
10
20
40
60
80
100
200
TEMPERATURE , °K



TEMPERATURE, °R
10
20
30
40
60
80
100
200
300
400
SPECIFIC HEAT
of TEFLON
(MOLDED)
SPECIFIC HEAT (C_p), joules/gm °K
2
1
0.4
0.2
0.1
.04
.02
.01
.004
.002
SPECIFIC HEAT (C_p), BTU/lb°R
0.4
0.2
0.1
.04
.02
.01
.004
.002
.001
TEMPERATURE, °K
5
10
20
30
40
60
80
100
200
300

SPECIFIC HEAT, ENTHALPY of POLYETHYLENE

Source of Data:

Sochava, I. V. and Trapeznikova, O. N., Sov. Phys. Doklady 2, 164-6 (1957).

Comments:

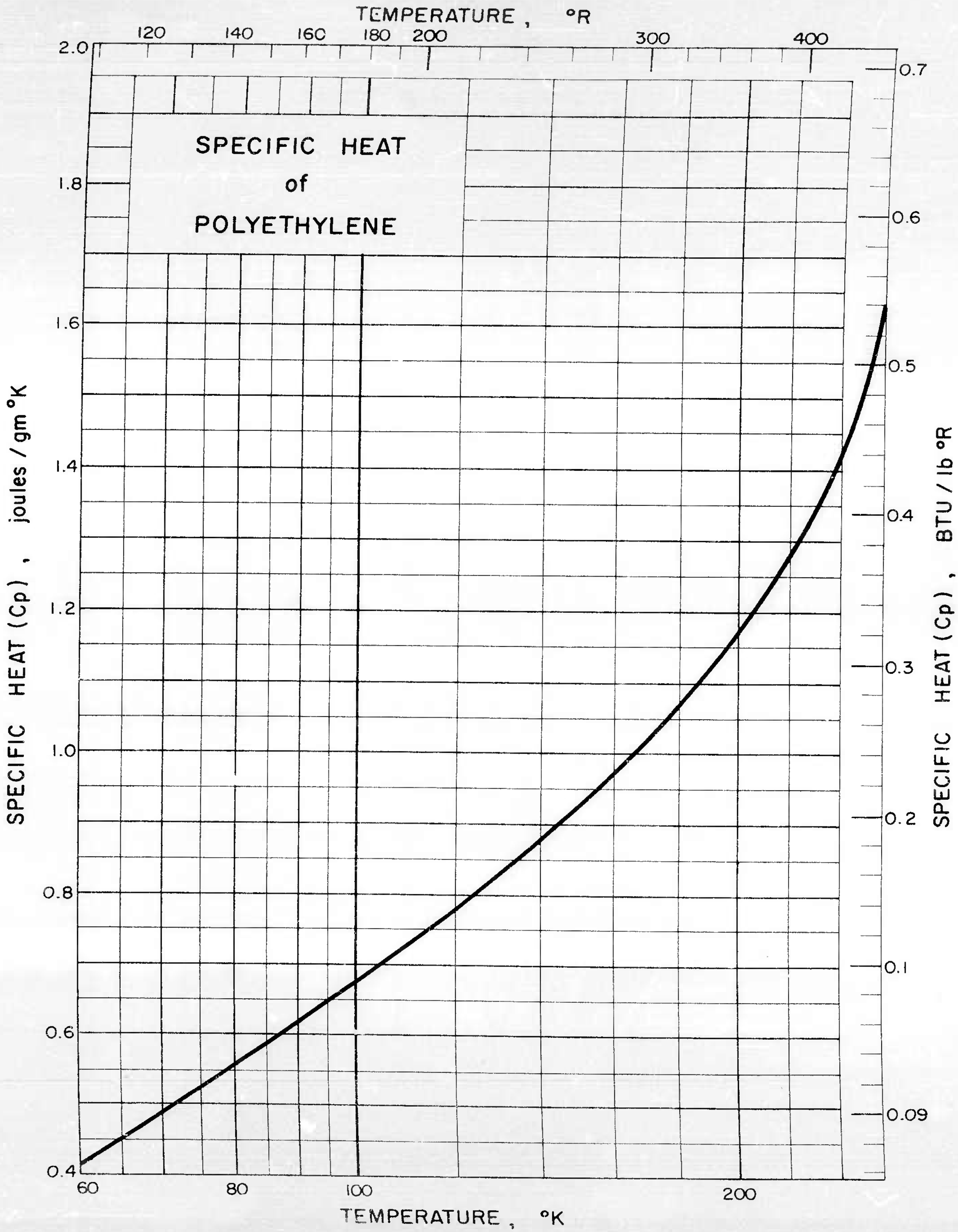
Since no specific heat measurements existed below 60°K, enthalpy values are given referenced to this temperature.

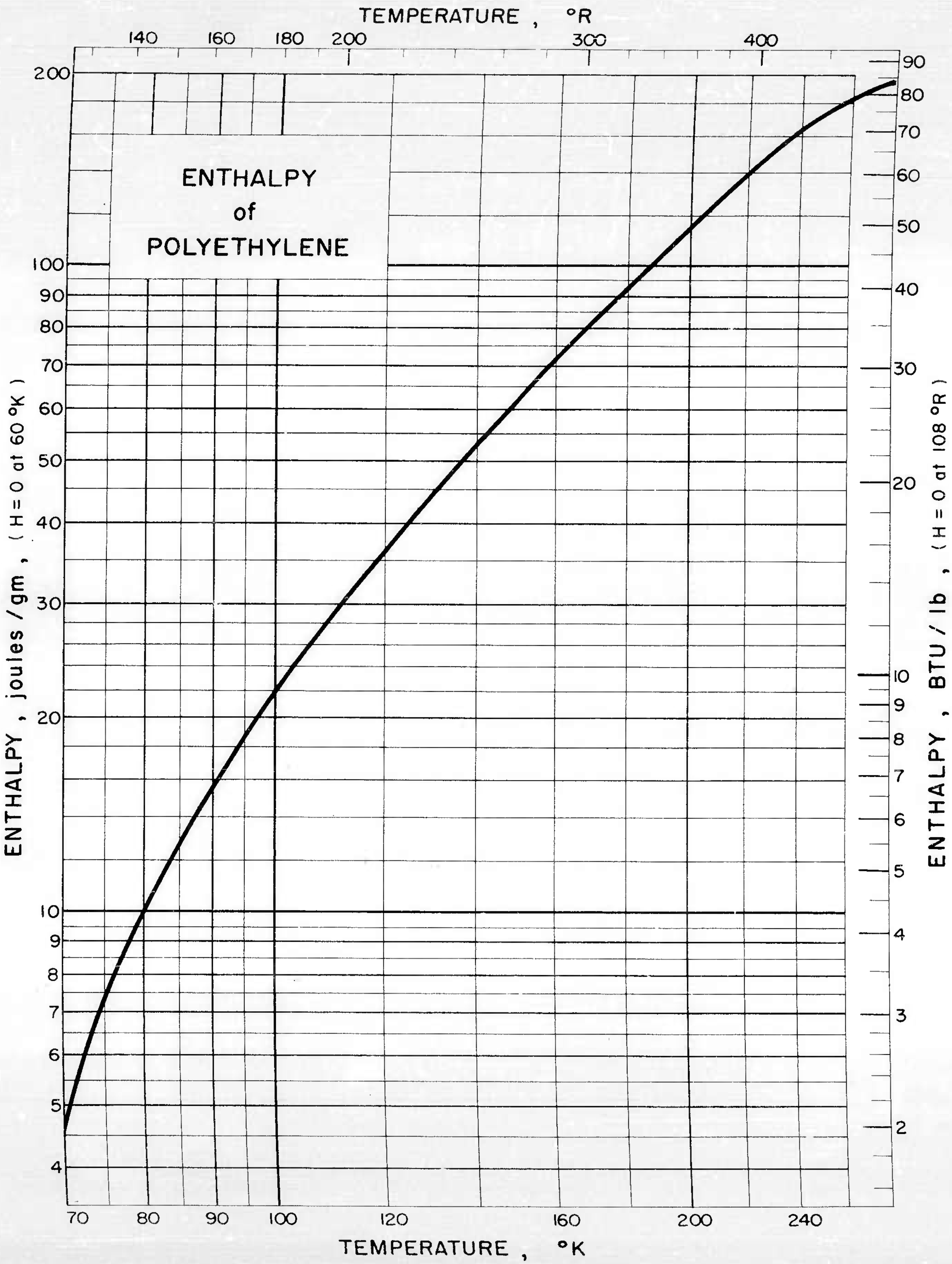
Table of Selected Values

T °K	C_p j/gm-°K	$H-H_{60}$ j/gm
60	0.418	
70	.496	4.57
80	.561	9.84
90	.619	15.7
100	.676	22.2
120	.778	36.8
140	.872	53.2
160	.971	71.7
180	1.07	92.1
200	1.17	114
220	1.28	139
240	1.43	166
260	1.63	196

$$H - H_{60} = \int_{60}^{T} C_p \, dT$$

RJC/JJG/VDA Issued: 12-14-59


TEMPERATURE , °R
120
140
160
180
200
300
400
SPECIFIC HEAT
of
POLYETHYLENE
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
SPECIFIC HEAT (Cp) , joules / gm °K
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.09
SPECIFIC HEAT (Cp) , BTU / lb °R
60
80
100
200
TEMPERATURE , °K


TEMPERATURE , °R
140
160
180
200
300
400
ENTHALPY
of
POLYETHYLENE
200
100
90
80
70
60
50
40
30
20
10
9
8
7
6
5
4
ENTHALPY , joules /gm , (H = 0 at 60 °K)
90
80
70
60
50
40
30
20
10
9
8
7
6
5
4
3
2
ENTHALPY , BTU / lb , (H = 0 at 108 °R)
70
80
90
100
120
160
200
240
TEMPERATURE , °K

SPECIFIC HEAT, ENTHALPY of BAKELITE VARNISH
(Formite Bakelite Varnish V11105)

Source of Data:

Hill, R. W. and Smith, P. L., Phil. Mag. 44, 636-44 (1953)

Comments:

Values tabulated below are smoothed values from the original data of Hill and Smith and may vary up to 3% from their work.

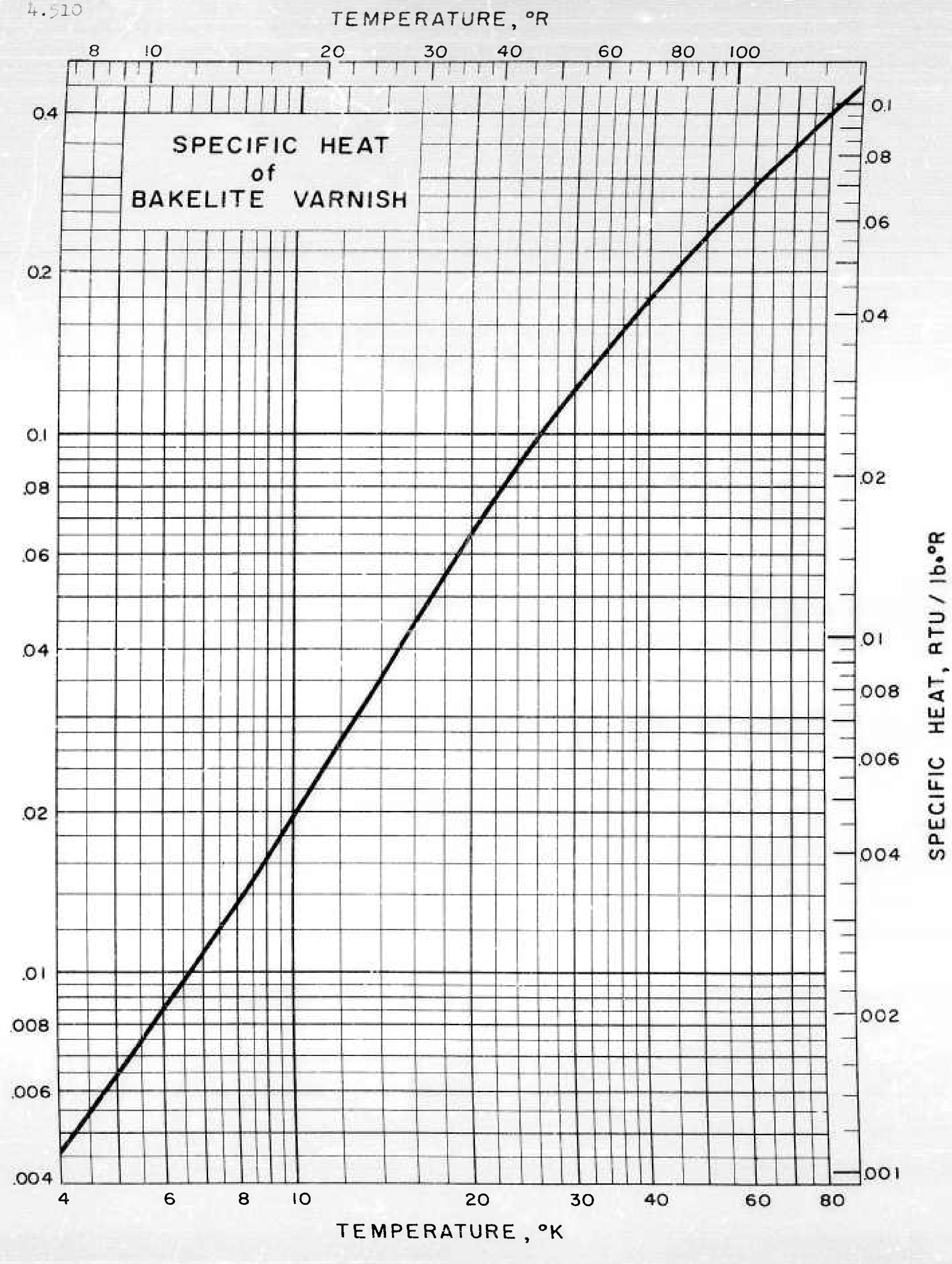
The sample was prepared by baking on an aluminum foil according to the manufacturer's specifications.

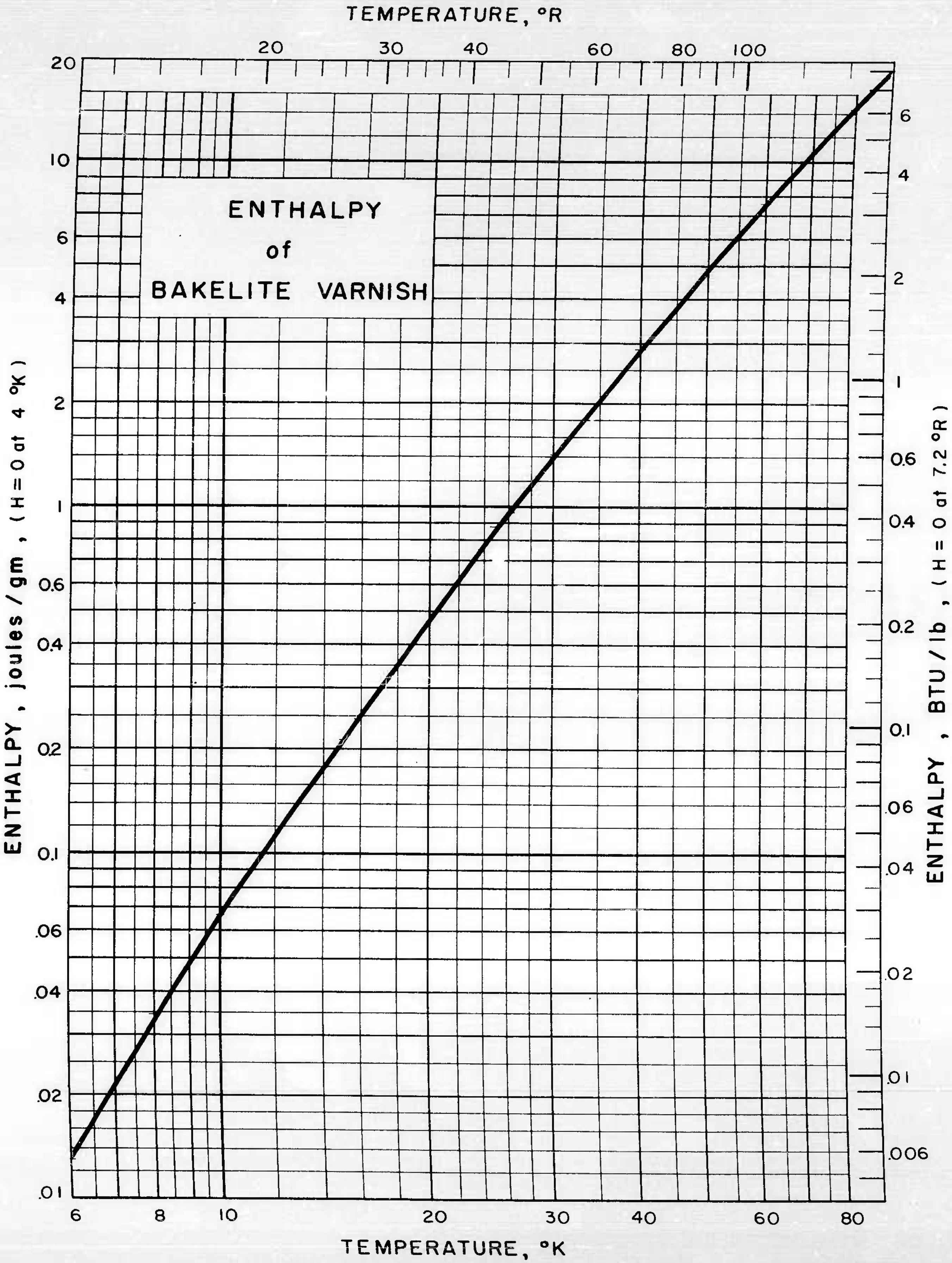
Table of Selected Values

Temp. °K	C_p j/gm-°K	$H-H_4$ j/gm
4	0.0046	
6	.0086	0.0130
8	.0134	.0347
10	.0192	.0672
15	.0418	.216
20	.0667	.487
25	.093	.886
30	.121	1.42
40	.179	2.91
50	.237	4.99
60	.293	7.64
70	.347	10.8
80	.400	14.6
90	.449	18.8

RJC/JJG/JRC Issued: 12-18-59

4.510


TEMPERATURE, °R
8
10
20
30
40
60
80
100
SPECIFIC HEAT
of
BAKELITE VARNISH
0.4
0.2
0.1
.08
.06
.04
.02
.01
.008
.006
.004
0.1
.08
.06
.04
.02
.01
.008
.006
.004
.002
.001
SPECIFIC HEAT, joules/gm-°K
SPECIFIC HEAT, BTU / lb-°R
4
6
8
10
20
30
40
60
80
TEMPERATURE, °K



TEMPERATURE, °R
20
30
40
60
80
100
ENTHALPY
of
BAKELITE VARNISH
ENTHALPY, joules / gm, (H = 0 at 4 °K)
20
10
6
4
2
1
0.6
0.4
0.2
0.1
.06
.04
.02
.01
ENTHALPY, BTU / lb, (H = 0 at 7.2 °R)
6
4
2
1
0.6
0.4
0.2
0.1
.06
.04
.02
.01
.006
6
8
10
20
30
40
60
80
TEMPERATURE, °K

SPECIFIC HEAT, ENTHALPY of GLYPTAL

Sources of Data:

Keesom, P. H. and Seidel, G., Phys. Rev. 113, 33-9 (1959)

Pearlman, N. and Keesom, P. H., Phys. Rev. 88, 398-405 (1952)

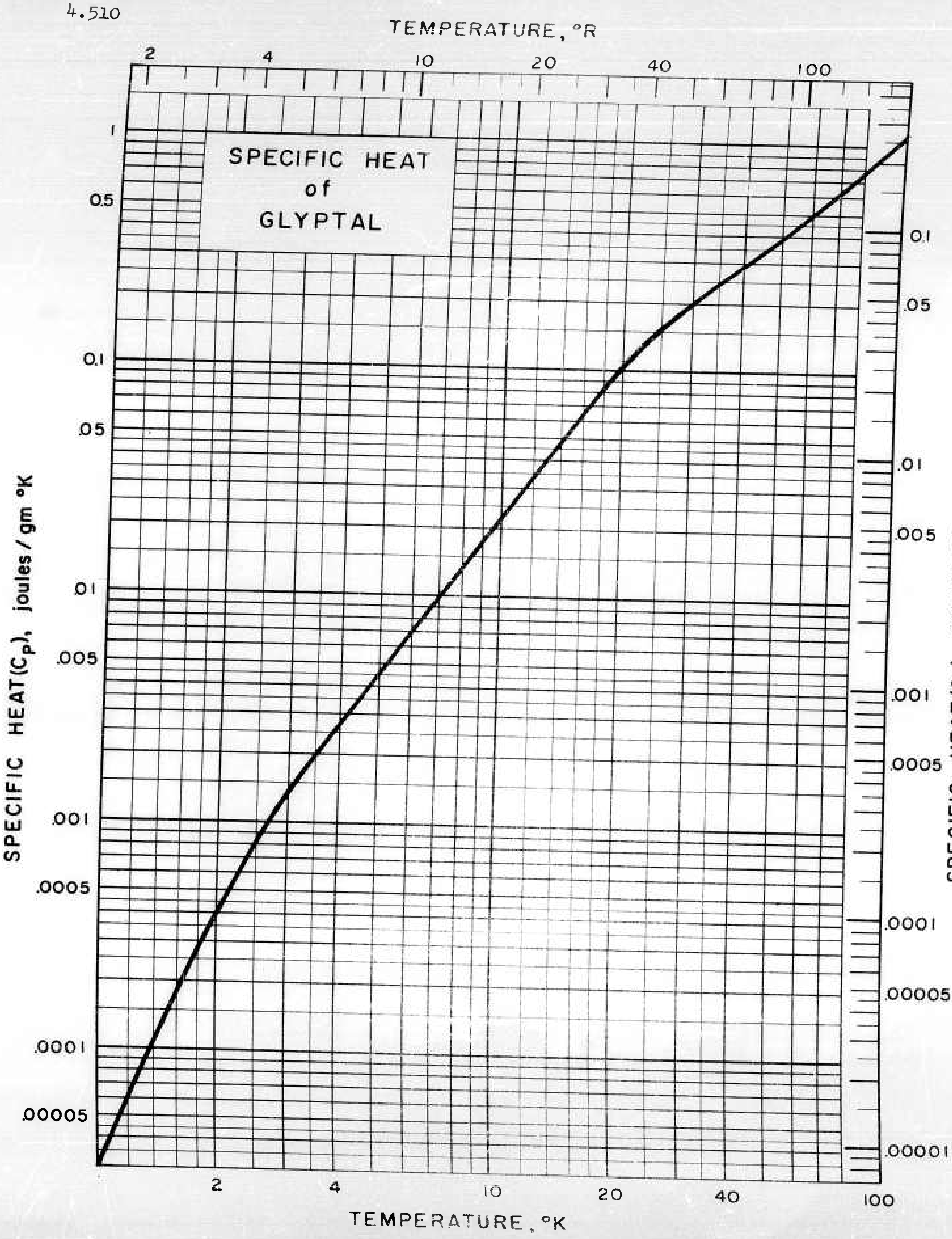
Comments:

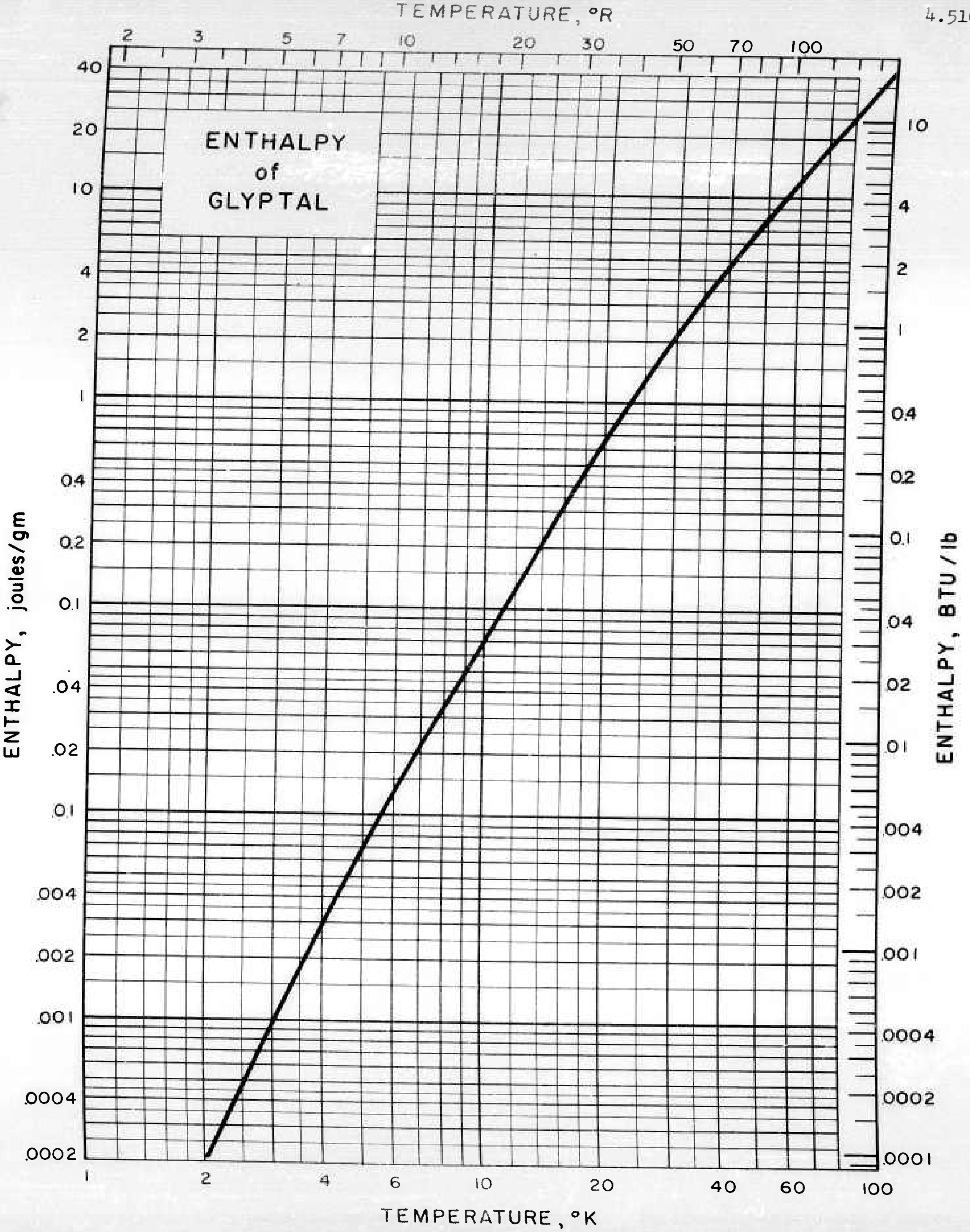
Pearlman and Keesom present the specific heat below 15°K by the approximate emperical relation $C \cong 2.2 \times 10^{-4} T^2$ j/gm-°K. Keesom and Seidel give the expression $C \cong 2.7 \times 10^{-5} T^3$ for representing the specific heat between 1.3° and 4.2°K. The values tabulated below are a graphical average of the two since both results claim no better than 20% accuracy, the former equation being based on measurements at 4°K and 10°K only.

Table of Selected Values

Temp. °K	C_p j/gm-°K	H j/gm
1	0.000 03	0.000 007
2	.000 4	.000 2
3	.001 4	.001 0
4	.002 6	.003 0
6	.007 3	.013
8	.014	.034
10	.022	.070
15	.057	.26
20	.11	.67
25	.16	1.3
30	.20	2.2
40	.29	4.7
50	.38	8.1
60	.49	12
70	.62	18
80	.79	25
90	.97	34
100	1.15	44

RJC/JJG/JRC Issued: 12-15-59


TEMPERATURE, °R
2
4
10
20
40
100
SPECIFIC HEAT
of
GLYPTAL
1
0.5
0.1
.05
.01
.005
.001
.0005
.0001
.00005
SPECIFIC HEAT(C_p), joules / gm °K
0.1
.05
.01
.005
.001
.0005
.0001
.00005
.00001
SPECIFIC HEAT(C_p), BTU/lb °R
2
4
10
20
40
100
TEMPERATURE, °K


TEMPERATURE, °R
2
3
5
7
10
20
30
50
70
100
ENTHALPY
of
GLYPTAL
ENTHALPY, joules/gm
40
20
10
4
2
1
0.4
0.2
0.1
.04
.02
.01
.004
.002
.001
.0004
.0002
ENTHALPY, BTU/lb
10
4
2
1
0.4
0.2
0.1
.04
.02
.01
.004
.002
.001
.0004
.0002
.0001
1
2
4
6
10
20
40
60
100
TEMPERATURE, °K

SPECIFIC HEAT, ENTHALPY of POLYVINYL ALCOHOL

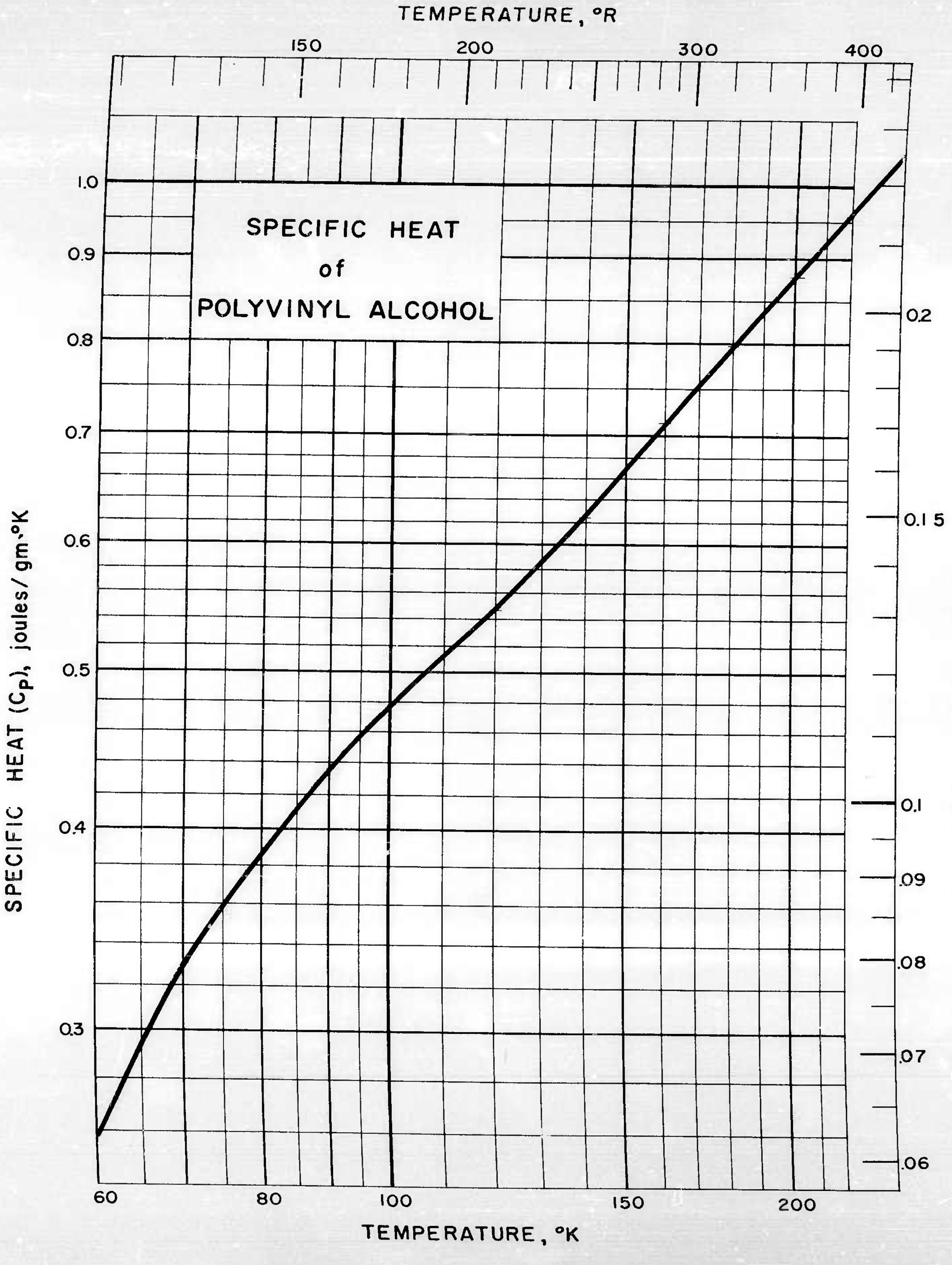
<u>Source of Data:</u>

Sochava, I. V. and Trapeznikova, O. N., Soviet Phys. Doklady <u>2</u>, 164-6 (1957)

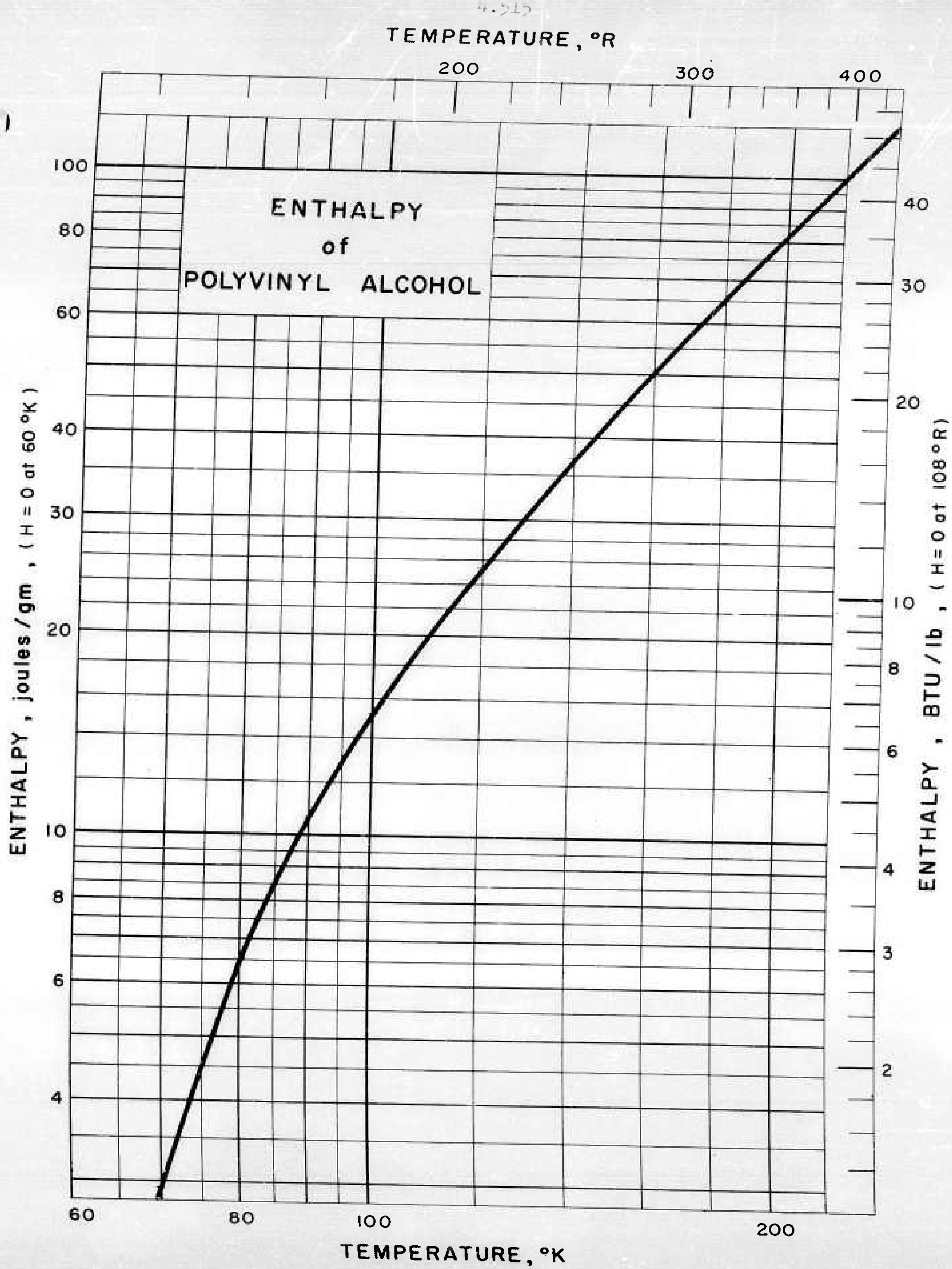
Table of Selected Values

Temp. °K	C_p j/gm-°K	H - H60 j/gm
60	0.257	
70	.331	2.95
80	.388	6.55
90	.436	10.7
100	.478	15.3
120	.546	25.5
140	.624	37.2
160	.713	50.5
180	.798	65.7
200	.879	82.4
220	.959	101
240	1.05	121

RJC/JJG/JRC Issued: 12-18-59
Revised: 5-20-60



TEMPERATURE, °R
150
200
300
400
SPECIFIC HEAT
of
POLYVINYL ALCOHOL
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
SPECIFIC HEAT (C_p), joules/gm-°K
0.2
0.1 5
0.1
.09
.08
.07
.06
SPECIFIC HEAT (C_p), BTU/lb-°R
60
80
100
150
200
TEMPERATURE, °K


4.515
TEMPERATURE, °R
200
300
400
ENTHALPY
of
POLYVINYL ALCOHOL
100
80
60
40
30
20
10
8
6
4
40
30
20
10
8
6
4
3
2
ENTHALPY, joules/gm, (H = 0 at 60 °K)
ENTHALPY, BTU/lb, (H = 0 at 108 °R)
60
80
100
200
TEMPERATURE, °K

APPENDIXES

TEMPERATURE INTERCONVERSION TABLE

CONVERSION FACTORS FOR UNITS OF LENGTH

CONVERSION FACTORS FOR UNITS OF AREA

CONVERSION FACTORS FOR UNITS OF VOLUME

CONVERSION FACTORS FOR UNITS OF MASS

CONVERSION FACTORS FOR UNITS OF PRESSURE

CONVERSION FACTORS FOR UNITS OF ENERGY

DATA SHEET AUTHOR IDENTIFICATION BY INITIALS

APPENDIX

Temperature Interconversion Table
(0 to 200°K)

°K	°C	°F	°R	°K	°C	°F	°R
0.	-273.16	-459.69	0.	100.	-173.16	-279.69	180.
3.16	-270.	-454.00	5.69	103.16	-170.	-274.00	185.69
5.38	-267.78	-450.	9.69	105.38	-167.78	-270.	189.69
5.55	-267.61	-449.69	10.	105.56	-167.60	-269.69	190.
10.	-263.16	-441.69	18.00	110.	-163.16	-261.69	198.00
10.94	-262.22	-440.	19.69	110.96	-162.20	-260.	199.69
11.11	-262.05	-439.69	20.	111.11	-162.05	-259.69	200.
13.16	-260.	-436.00	23.69	113.16	-160.	-256.00	203.69
16.49	-256.67	-430.	29.69	116.49	-156.67	-250.	209.69
16.67	-256.49	-429.69	30.	116.67	-156.49	-249.69	210.
20.	-253.16	-423.69	36.00	120.	-153.16	-243.69	216.00
22.05	-251.11	-420.	39.69	122.05	-151.11	-240.	219.69
22.22	-250.94	-419.69	40.	122.22	-150.94	-239.69	220.
23.16	-250.	-418.00	41.69	123.16	-150.	-238.00	221.69
27.60	-245.56	-410.	49.69	127.60	-145.56	-230.	229.69
27.78	-245.38	-409.69	50.	127.78	-145.38	-229.69	230.
30.	-243.16	-405.69	54.00	130.	-143.16	-225.69	234.00
33.16	-240.	-400.	59.69	133.16	-140.	-220.	239.69
33.33	-239.83	-399.69	60.	133.33	-139.83	-219.69	240.
38.72	-234.44	-390.	69.69	138.72	-134.44	-210.	249.69
38.89	-234.27	-389.69	70.	138.89	-134.27	-209.69	250.
40.	-233.16	-387.69	72.00	140.	-133.16	-207.69	252.00
43.16	-230.	-382.00	77.69	143.16	-130.	-202.00	257.69
44.27	-228.89	-380.	79.69	144.27	-128.89	-200.	259.69
44.44	-228.72	-379.69	80.	144.44	-128.62	-199.69	260.
49.83	-223.33	-370.	89.69	149.83	-123.33	-190.	269.69
50.	-223.16	-369.69	90.	150.	-123.16	-189.69	270.
53.16	-220.	-364.00	95.69	153.16	-120.	-184.00	275.69
55.38	-217.78	-360.	99.69	155.38	-117.78	-180.	279.69
55.56	-217.60	-359.69	100.	155.56	-117.60	-179.69	280.
60.	-213.16	-351.69	108.00	160.	-113.16	-171.69	288.00
60.94	-212.22	-350.	109.69	160.94	-112.22	-170.	289.69
61.11	-212.05	-349.69	110.	161.11	-112.05	-169.69	290.
63.16	-210.	-346.00	113.69	163.16	-110.	-166.00	293.69
66.49	-206.67	-340.	119.69	166.49	-106.67	-160.	299.69
66.67	-206.49	-339.69	120.	166.67	-106.49	-159.69	300.
70.	-203.16	-333.69	126.00	170.	-103.16	-153.69	306.00
72.05	-201.11	-330.	129.69	172.05	-101.11	-150.	309.69
72.22	-200.94	-329.69	130.	172.22	-100.94	-149.69	310.
73.16	-200.	-328.00	131.69	173.16	-100.	-148.00	311.69
77.60	-195.56	-320.	139.69	177.60	-95.56	-140.	319.69
77.78	-195.38	-319.69	140.	177.78	-95.38	-139.69	320.
80.	-193.16	-315.69	144.00	180.	-93.16	-135.69	324.00
83.16	-190.	-310.	149.69	183.16	-90.	-130.	329.69
83.33	-189.83	-309.69	150.	183.33	-89.83	-129.69	330.
88.72	-184.44	-300.	159.69	188.72	-84.44	-120.	339.69
88.89	-184.27	-299.69	160.	188.89	-84.27	-119.69	340.
90.	-183.16	-297.69	162.00	190.	-83.16	-117.69	342.00
93.16	-180.	-292.00	167.69	193.16	-80.	-112.00	347.69
94.27	-178.89	-290.	169.69	194.27	-78.89	-110.	349.69
94.44	-178.72	-289.69	170.	194.44	-78.72	-109.69	350.
99.83	-173.33	-280.	179.69	199.83	-73.33	-100.	359.69
100.	-173.16	-279.69	180.	200.	-73.16	-99.69	360.

°K °C	°R °F
1	1.8
2	3.6
3	5.4
4	7.2
5	9.0
6	10.8
7	12.6
8	14.4
9	16.2
10	18.0

°R °F	°K °C
1	0.56
2	1.11
3	1.67
4	2.22
5	2.78
6	3.33
7	3.89
8	4.44
9	5.00
10	5.56
11	6.11
12	6.67
13	7.22
14	7.78
15	8.33
16	8.89
17	9.44
18	10.00

APPENDIX

Temperature Interconversion Table
(200 to 400°K)

°K	°C	°F	°R	°K	°C	°F	°R
200.	-73.16	-99.69	360.	300.	26.84	80.31	540.
203.16	-70.	-94.00	365.69	303.16	30.	86.00	545.69
205.38	-67.78	-90.	369.69	305.38	32.22	90.	549.69
205.56	-67.60	-89.99	370.	305.56	32.40	90.31	550.
210.	-63.16	-81.69	378.00	310.	36.84	98.31	558.00
210.94	-62.22	-80.	379.69	310.94	37.78	100.	559.69
211.11	-62.05	-79.69	380.	311.11	37.95	100.31	560.
213.16	-60.	-76.00	383.69	313.16	40.	104.00	563.69
216.41	-56.67	-70.	389.69	316.41	43.33	110.	569.69
216.67	-56.49	-69.69	390.	316.67	43.51	110.31	570.
220.	-53.16	-63.69	396.00	320.	46.84	116.31	576.00
222.05	-51.11	-60.	399.69	322.05	48.89	120.	579.69
222.22	-50.94	-59.69	400.	322.22	49.06	120.31	580.
223.16	-50.	-58.00	401.69	323.16	50.	122.00	581.69
227.60	-45.56	-50.	409.69	327.60	54.44	130.	589.69
227.78	-45.38	-49.69	410.	327.78	54.62	130.31	590.
230.	-43.16	-45.69	414.00	330.	56.84	134.31	594.00
233.16	-40.	-40.	419.69	333.16	60.	140.	599.69
233.33	-39.83	-39.69	420.	333.33	60.17	140.31	600.
238.72	-34.44	-30.	429.69	338.72	65.56	150.	609.69
238.89	-34.27	-29.69	430.	338.89	65.73	150.31	610.
240.	-33.16	-27.69	432.00	340.	66.84	152.31	612.00
243.16	-30.	-22.00	437.69	343.16	70.	158.00	617.69
244.27	-28.89	-20.	439.69	344.27	71.11	160.	619.69
244.44	-28.72	-19.69	440.	344.44	71.28	160.31	620.
249.83	-23.33	-10.	449.69	349.83	76.67	170.	629.69
250.	-23.16	-9.69	450.	350.	76.84	170.31	630.
253.16	-20.	-4.00	455.69	353.16	80.	176.00	635.69
255.38	-17.78	0.	459.69	355.38	82.22	180.	639.69
255.56	-17.60	+.31	460.	355.56	82.40	180.31	640.
260.	-13.16	+8.31	468.00	360.	86.84	188.31	648.00
260.94	-12.22	10.	469.69	360.94	87.78	190.	649.69
261.11	-12.05	10.31	470.	361.11	87.95	190.31	650.
263.16	-10.	14.00	473.69	363.16	90.	194.00	653.69
266.49	-6.67	20.	479.69	366.49	93.33	200.	659.69
266.67	-6.49	20.31	480.	366.67	93.51	200.31	660.
270.	-3.16	26.31	486.00	370.	96.84	206.31	666.00
272.05	-1.11	30.	489.69	372.05	98.89	210.	669.69
272.22	-.94	30.31	490.	372.22	99.06	210.31	670.
273.16	0.	32.00	491.69	373.16	100.	212.00	671.69
277.60	+4.44	40.	499.69	377.60	104.44	220.	679.69
277.78	4.62	40.31	500.	377.78	104.62	220.31	680.
280.	6.84	44.31	504.00	380.	106.84	224.31	684.00
283.16	10.	50.	509.69	383.16	110.	230.	689.69
283.33	10.17	50.31	510.	383.33	110.17	230.31	690.
288.72	15.56	60.	519.69	388.72	115.56	240.	699.69
288.89	15.73	60.31	520.	388.89	115.73	240.31	700.
290.	16.84	62.31	522.00	390.	116.84	242.31	702.00
293.16	20.	68.00	527.69	393.16	120.	248.00	707.69
294.27	21.11	70.	529.69	394.27	121.11	250.	709.69
294.44	21.28	70.31	530.	394.44	121.28	250.31	710.
299.83	26.67	80.	539.69	399.83	126.67	260.	719.69
300.	26.84	80.31	540.	400.	126.84	260.31	720.

°K °C	°R °F
1	1.8
2	3.6
3	5.4
4	7.2
5	9.0
6	10.8
7	12.6
8	14.4
9	16.2
10	18.0

°R °F	°K °C
1	0.56
2	1.11
3	1.67
4	2.22
5	2.78
6	3.33
7	3.89
8	4.44
9	5.00
10	5.56
11	6.11
12	6.67
13	7.22
14	7.78
15	8.33
16	8.89
17	9.44
18	10.00

APPENDIX

Conversion Factors
for
Units of Length and Area

CONVERSION FACTORS FOR UNITS OF LENGTH

Multiply ↓ by appropriate entry to obtain →	cm	mm	μ	mμ	Å
1 Centimeter (cm)	1	10	10^{4}	10^{7}	10^{8}
1 Millimeter (mm)	10^{-1}	1	10^{3}	10^{6}	10^{7}
1 Micron (μ)	10^{-4}	10^{-3}	1	10^{3}	10^{4}
1 Millimicron (mμ)	10^{-7}	10^{-6}	10^{-3}	1	10
1 Angstrom Unit (Å)	10^{-8}	10^{-7}	10^{-4}	10^{-1}	1

CONVERSION FACTORS FOR UNITS OF LENGTH - Cont.

Multiply ↓ by appropriate entry to obtain →	cm	m	in	ft	yd
1 cm	1	0.01	0.3937	0.032808333	0.010936111
1 m	100.	1	39.37	3.2808333	1.0936111
1 in	2.5400051	0.025400051	1	0.083333333	0.027777778
1 ft	30.480061	0.30480061	12.	1	0.33333333
1 yd	91.440183	0.91440183	36.	3.	1

CONVERSION FACTORS FOR UNITS OF AREA

Multiply ↓ by appropriate entry to obtain →	cm^2	m^2	sq in	sq ft	sq yd
1 cm^2	1	10^{-4}	0.15499969	1.0763867×10^{-3}	1.1959853×10^{-4}
1 m^2	10^{4}	1	1549.9969	10.763867	1.1959853
1 sq in	6.4516258	6.4516258×10^{-4}	1	6.9444444×10^{-3}	7.7160494×10^{-4}
1 sq ft	929.03412	0.092903412	144.	1	0.11111111
1 sq yd	8361.3070	0.83613070	1296.	9.	1

APPENDIX

Conversion Factors

CONVERSION FACTORS FOR UNITS OF VOLUME

Multiply by appropriate entry to obtain →	ml	liter	gal
1 cm^3	0.9999720	0.9999720×10^{-3}	2.6417047×10^{-4}
1 cu in	16.38670	1.638670×10^{-2}	4.3290043×10^{-3}
1 cu ft	28316.22	28.31622	7.4805195
1 ml	1	0.001	2.641779×10^{-4}
1 liter	1000.	1	0.2641779
1 gal	3785.329	3.785329	1

CONVERSION FACTORS FOR UNITS OF VOLUME - Cont.

Multiply by appropriate entry to obtain →	cm^3	cu in	cu ft
1 cm^3	1	0.061023378	3.5314455×10^{-5}
1 cu in	16.387162	1	5.7870370×10^{-4}
1 cu ft	28317.017	1728.	1
1 ml	1.000028	0.06102509	3.531544×10^{-5}
1 liter	1000.028	61.02509	0.03531544
1 gal	3785.4345	231.	0.13368056

APPENDIX

Conversion Factors

CONVERSION FACTORS FOR UNITS OF MASS

Multiply by appropriate entry to obtain →	g	kg	lb	metric ton	ton
1 g	1	10^{-3}	2.2046223×10^{-3}	10^{-6}	1.1023112×10^{-6}
1 kg	10^{3}	1	2.2046223	10^{-3}	1.1023112×10^{-3}
1 lb	453.59243	0.45359243	1	4.5359243×10^{-4}	0.0005
1 metric ton	10^{6}	10^{3}	2204.6223	1	1.1023112
1 ton	907184.86	907.18486	2000.	0.90718486	1

APPENDIX

Conversion Factors for Units of Pressure

CONVERSION FACTORS FOR UNITS OF PRESSURE

Multiply by appropriate entry to obtain →	$dyne/cm^2$	bar	atm	$kg(wt)/cm^2$	mm Hg	in Hg	lb(wt)/sq in
1 $dyne/cm^2$	1	10^{-6}	0.9869233×10^{-6}	1.0197162×10^{-6}	7.500617×10^{-4}	2.952993×10^{-5}	1.4503830×10^{-5}
1 bar	10^6	1	0.9869233	1.0197162	750.0617	29.52993	14.503830
1 atm	1013250.	1.013250	1	1.0332275	760.	29.92120	14.696006
1 $kg(wt)/cm^2$	980665.	0.980665	0.9678411	1	735.5592	28.95897	14.223398
1 mm Hg	1333.2237	1.3332237×10^{-3}	1.3157895×10^{-3}	1.3595098×10^{-3}	1	0.03937	0.019336850
1 in Hg	33863.95	0.03386395	0.03342112	0.03453162	25.40005	1	0.4911570
1 lb(wt)/sq in	68947.31	0.06894731	0.06804570	0.07030669	51.71473	2.036009	1

APPENDIX

Conversion Factors
for
Units of Energy

CONVERSION FACTORS FOR UNITS OF ENERGY

Multiply by appropriate entry to obtain →	g mass (energy equiv)	abs. joule	int. joule	cal	I. T. cal	BTU	int. kilowatt -hr
1 g mass (energy equiv)	1	8.98656×10^{13}	8.98508×10^{13}	2.14784×10^{13}	2.14644×10^{13}	8.51775×10^{10}	2.49586×10^{7}
1 abs. joule	1.112772×10^{-14}	1	0.999835	0.239006	0.238849	0.947831×10^{-3}	2.77732×10^{-7}
1 int. joule	1.112956×10^{-14}	1.000165	1	0.239045	0.238889	0.947988×10^{-3}	2.777778×10^{-7}
1 cal	4.65584×10^{-14}	4.1840	4.1833	1	0.999346	3.96573×10^{-3}	1.162030×10^{-6}
1 I. T. cal	4.65888×10^{-14}	4.18674	4.18605	1.000654	1	3.96832×10^{-3}	1.162791×10^{-6}
1 BTU	1.174019×10^{-11}	1055.040	1054.866	252.161	251.996	1	2.93018×10^{-4}
1 int. kilowatt-hr	4.00664×10^{-8}	3,600,594.	3,600,000.	860,563.	860,000.	3412.76	1
1 horsepower-hr	2.98727×10^{-8}	2,684,525.	2,684,082.	641,617.	641,197.	2544.48	0.745578
1 ft-lb(wt)	1.508720×10^{-14}	1.355821	1.355597	0.324049	0.323837	1.285089×10^{-3}	3.76555×10^{-7}
1 cu ft - lb(wt)/sq in	2.17256×10^{-12}	195.2382	195.2060	46.6630	46.6325	0.1850529	5.42239×10^{-5}
1 liter-atm	1.127548×10^{-12}	101.3278	101.3111	24.2179	24.2021	0.0960417	2.81420×10^{-5}

Conversion Factors

CONVERSION FACTORS FOR UNITS OF ENERGY - Cont.

Multiply by appropriate entry to obtain →	ft-lb(wt)	cu ft-lb(wt)/sq in.	liter-atm	horsepower-hr
1 g mass(energy equiv)	6.62814×10^{13}	4.60287×10^{11}	8.86880×10^{11}	3.34754×10^{7}
1 abs. joule	0.737561	5.12195×10^{-3}	9.86896×10^{-3}	3.72505×10^{-7}
1 int. joule	0.737682	5.12279×10^{-3}	9.87058×10^{-3}	3.72567×10^{-7}
1 cal	3.08595	2.14302×10^{-2}	4.12917×10^{-2}	1.558562×10^{-6}
1 I. T. cal	3.08797	2.14443×10^{-2}	4.13187×10^{-2}	1.559582×10^{-6}
1 BTU	778.156	5.40386	10.41215	3.93008×10^{-4}
1 int. kilowatt-hr	2,655,656.	18442.06	35534.1	1.341241
1 horsepower-hr	1,980,000.	13750.	26493.5	1
1 ft-lb(wt)	1	6.94444×10^{-3}	1.338054×10^{-2}	5.05051×10^{-7}
1 cu ft - lb(wt)/sq in	144.	1	1.926797	7.27273×10^{-5}
1 liter-atm	74.7354	5.18996	1	3.77452×10^{-5}

DATA SHEET AUTHOR IDENTIFICATION FROM INITIALS

VDA = Vincent D. Arp
EHB = Edmund H. Brown
JAB = James A. Brennan
PLB = Paul L. Barrick
WWB = William W. Bulla
JRC = Jerry R. Cahoon
DBC = Dudley B. Chelton
RJC = Robert J. Corruccini
FEEG = Frank E. E. Germann
JJG = John J. Gniewek
RDG = Robert D. Goodwin
DEJ = Donald E. Jordan
VJJ = Victor J. Johnson
DBM = Douglas B. Mann
GRM = Genevieve R. Michela
JM = John Macinko
RLP = Robert L. Powell
GAR = George A. Reynolds
RFR = Ross F. Robbins
HMR = Hans M. Roder
RBS = Russell B. Scott
RS = Richard Stewart
RVS = Raymond V. Smith
BDT = Bryce D. Troyer
KDT = Klaus D. Timmerhaus
DAV = Donald A. Van Gundy
WJV = William J. Veigele